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PRUNING VINIFERA GRAPEVINES

A. J. WINKLER

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B. H. Crocheron, Director, California Agricultural Extension Service.

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PRUNING VINIFERA GRAPEVINES[1]

A. J. WINKLER[2]

By separating the influence of pruning from the influence of crop on the growth and fruiting of the vine, new principles of the response of the vine to pruning have been discovered. It has been clearly shown that pruning depresses[3] the capacity of the vine for both growth and production. By employing longer (less severe) types of pruning, that is, by retaining more wood at the winter pruning and accompanying this with some method of thinning to regulate the crop, a method of procedure has been developed which has resulted in the improvement of both quality and yield.

DEFINITION AND OBJECTS OF PRUNING

Pruning consists in the removal of canes, shoots, leaves, and other vegetative parts of the vine. The removal of flower clusters, clusters, or parts of clusters is *thinning*. Although some of the effects of thinning are similar to those of pruning, it is not usually considered to be pruning. The removal of the ripe fruit is *harvesting*.

The objects of pruning are: (1) to aid in establishing and maintaining the vine in a form which will save labor and facilitate the necessary vineyard operations, such as cultivation, the control of diseases and insects, thinning, and harvesting; (2) to distribute the bearing wood over every vine, between vines, and between years in accordance with the capacity of the spurs (or canes) and vines in order to equalize production in the interest of larger average crops of high-quality fruit; and (3) to lessen or eliminate the cost of thinning in the control of crop. Pruning is the cheapest means of reducing the number of clusters.

[1] The previous publications of this Station dealing with pruning—Bulletins 241 and 246, Vine Pruning in California; Circular 245, Pruning Systems; Circular 248, Common Errors in Pruning; and Circular 277, Head, Cane, and Cordon Pruning of Vines—are out of print. Rather than revise one or several of these, it seems a suitable time for the publication of a new circular which will combine the material of these earlier reports which experience has proved sound with the results of our pruning investigations since Bulletins 241 and 246 were revised in 1921.

[2] Associate Professor of Viticulture and Associate Viticulturist in the Experiment Station.

[3] Winkler, A. J. Pruning and thinning experiments with grapes. California Agr. Exp. Sta. Bul. 519:1–56. 1931.

Pruning and Training.—Training, both by derivation and usage, includes certain practices supplementary to pruning which are necessary to give the developing vine a desirable shape. It consists principally in attaching the vine and its growth to various forms of support. Pruning determines the number and position of the buds that develop, while training determines the form and direction of the trunk and arms and the position of the shoots that develop from the buds retained at pruning. Pruning influences particularly the quantity and quality of the fruit; training the form of the permanent portions of the vine.

Although the methods employed and the object to be attained in developing young vines differ from those of the pruning of bearing vines, the response in both cases is the same—pruning is always depressing. In the young vine, however, the vineyardist, who is interested primarily in the development of a single strong shoot with several well-placed laterals to form the permanent framework of the vine, sacrifices some of the energy of the plant in order to obtain what he wants—a well-shaped vine—as cheaply and as easily as possible. In the bearing vine, on the other hand, the pruner is interested in the production of both wood and crop, since a proper balance between them is essential to the development of fruit of good quality and the continued production of good crops. For this reason it is sometimes convenient for the sake of clarity to distinguish between the development of a young vine of desirable form—training—and the maintenance of the established form and the regulation of fruiting of bearing vines—pruning.

Vigor and Capacity.—Confusion regarding the response of the vine to pruning has been due to a loose use of the term "vigor" and to a failure to separate the effect of pruning on vine growth from the accompanying influence of crop. The term "vigor" has been used both qualitatively in the sense of "rate of growth" and quantitatively in the sense of "capacity for growth and fruiting." A young vine may show great vigor in the qualitative sense of "rate of growth" and yet in the quantitative sense its capacity for growth and fruiting may be much less than that of an old and relatively mature vine. Similarly, if a vine is pruned severely, the number of shoots the vine produces is reduced, and the shoots may be more vigorous (grow faster) than the shoots of a lightly pruned vine. The vine will be more vigorous, but it has less capacity for production; that is, it will make less total growth. On a single shoot vigor and capacity for production vary together; that is, a vigorous shoot has large capacity and a weak shoot small capacity.

To aid in a better understanding of the characteristic responses of the vine to pruning it is necessary to employ the two terms "vigor" and

"capacity." These terms are defined as follows: *Vigor* is the quality or condition of active growth of the vine or a part of the vine. It refers essentially to rate of growth. *Capacity* is the quantity of action with respect to growth and production of which the vine or a part of the vine is capable.

Although the influence of pruning on vigor is utilized in developing the desired form of trunk in the training of young vines, once the vineyard is established the grower is primarily concerned with the capacity of the vines to produce large crops of good fruit over a long period of years. It must be borne in mind, however, that the capacity to produce fruit is dependent on the production of wood; hence, to produce heavy crops over a period of years a vine must not only be capable of maturing a good crop of fruit each year but also of maturing a good growth of wood.

The influence of crop on vigor and capacity is very similar to that of pruning. Light crops favor vigorous shoot growth and thereby increase the capacity of the vine. Overbearing reduces vigor, and as a result of the slower rate of shoot growth the total amount of wood produced is small so that the capacity of the vine is decreased. The proper balance of crop, pruning, and growth is then one which will give the largest *regular* crops of high-quality fruit over a long period of years.

THE PRINCIPLES OF PRUNING

In order to accomplish the objects set forth in our definition of pruning it is necessary to take into consideration certain principles of plant physiology as they apply to the vine. The principles are based on our knowledge of the response of the vine to changes in its nutrition resulting from the removal of vegetative or fruiting parts and on our understanding of the growth and fruiting habits of the vine. The principles of pruning, with supporting data for those established in the pruning investigations at the Branch of the College of Agriculture, at Davis, California, may be stated as follows:

1. The removal of living vegetative parts of the vine is depressing; that is, pruning of any sort at any time decreases the capacity of the vine. The principal effect of pruning during the dormant season which influences vine growth and bearing is a decrease of leaf activity. Accompanying this decrease is a slower development of the shoots and a decrease in the bulk of the whole vine and its capacity to bear fruit when compared with unpruned vines of the same age on which the crop is controlled entirely by thinning.

The total leaf activity of the vine depends on the number, size, and quality of its leaves and on the length of time during which these leaves are active. Table 1 shows that the smaller the amount of wood removed by pruning, the more rapidly the leaves develop and the greater the total foliage produced during the next growing season, provided that the crop was regulated by thinning.

TABLE 1

THE WEIGHT AND ESTIMATED ACTIVITY OF THE LEAVES WITH SEVERAL TYPES OF PRUNING ON MUSCAT AND ALICANTE BOUSCHET VINES

Type of pruning	Weight of leaves			Relative weight; no pruning = 100	
	May 5	June 24	October 15	October 15 weighing	Average of the three weighings
	1	*2*	*3*	*4*	*5*
	pounds	*pounds*	*pounds*		
No pruning, part crop*	8.5	13.1	19.4	100	100
Cane pruning, part crop*	1.9	7.4	14.9	77	52
Normal pruning, all crop	0.4	3.3	7.6	40	24
Severe pruning, all crop	0.1	1.8	6.7	35	17

* Crop regulated by flower-cluster thinning about four weeks before blooming.

As shown in table 1, the nonpruned vines had produced a greater weight of leaves by May 5 than the normally pruned vines produced by October 15. Likewise, the nonpruned vines had a greater weight of leaves to a vine on May 5 than the cane-pruned vines had on June 24. In other words, it required only 35 days for the nonpruned vines to produce 8.5 pounds of leaves, while 85 days were required for the cane-pruned vines to produce 7.4 pounds of leaves, and 198 days for the normally pruned vines to produce 7.6 pounds of leaves. The great advantage in total weight of leaves to a vine in favor of the unpruned vines prevailed throughout the growing season, and on October 15 they had 1.3 times the weight of leaves of the cane-pruned vines, 2.5 times that of the normally pruned vines, and 3.0 times that of the severely pruned vines. The above influence of pruning on leaf development is substantiated by a large number of leaf weighings of other varieties.

The effect of type of pruning on leaf activity is indicated in column 4 of table 1. If total weight (which is reduced to relative weights to facilitate comparisons) on October 15 alone is considered, cane pruning reduced leaf weight 23 per cent, normal pruning 60 per cent, and severe pruning 65 per cent. This comparison, however, does not take into account the earlier development of the leaves and the consequently

longer period of time during which the leaves on the vines with decreased pruning function.

A comparison which makes use of both weight and time would give a more accurate indication of the retarding effect of pruning on leaf activity. To make such a comparison the ratios of the weights of the leaves for the several types of pruning at each date of weighing to that of the nonpruned vines was obtained. The average ratios for the three weighings are shown in column 5 of table 1. Here again the average of the weights at the several dates of weighing for the nonpruned vines is listed as 100. By using the average ratios for the three weighings under each type of pruning, the loss of leaf activity by cane pruning is 48 per cent, that by normal pruning is 76 per cent, and that by severe pruning is 83 per cent. The percentage reductions in leaf activity following the different types of pruning appear large, but they are corroborated by measurements of the effects of pruning on the increase of bulk of the whole vine and on the character of the fruit and the amount of crop borne.

The growth of the nonpruned vines was rapid early in the season but owing to the many shoots that developed, the rate of growth rapidly diminished so that very little additional elongation occurred between July 1 and the end of the growing season. With this type of growth there is very little competition between additional vegetative growth and the fruit for the food materials in the vine after midseason when the fruit is maturing. The more severely pruned vines, on the contrary, start growth less rapidly, and, owing to the relatively few shoots that develop, the rapid growth characteristic of the first part of the season in all vines continues to the end of the growing season. Thus the competition for the food material in the vine by the fruit and new vegetative growth continues to be keen throughout the season. The character of growth of intermediate types of pruning is intermediate between that of the nonpruned and that of the severely pruned vines.

As might be expected, the growth of the whole vine varied with the weight of leaves and the time during which they were functioning. Vines which had been pruned to different degrees of severity for three, five, and seven years had the relative differences in weight shown in table 2.

The figures of table 2 show that the relative weight of vine varied, as did that of the leaves, inversely as the severity of the pruning. Since these vines were treated alike except in the manner of pruning and since bearing was prevented by the removal of all flower clusters several weeks before blooming, the differences in growth are undoubtedly due to differences in pruning. It seems logical, therefore, to conclude

that, other things being equal, the less the pruning the greater the leaf activity and consequently the greater the total growth of the vine.

Table 3 shows the decrease in capacity for bearing of vines with increased severity of pruning.

TABLE 2

THE RELATIVE DECREASE IN WEIGHT OF VINE WITH INCREASED PRUNING

Type of pruning	Alicante Bouschet		Monukka
	3 years old	5 years old	7 years old
	Relative weight; no pruning=100		
No pruning, no crop	100	100	100
Normal pruning, no crop	65	63	75
Severe pruning, no crop	44	41	69

TABLE 3

THE EFFECT OF TYPE OF PRUNING ON THE BEARING CAPACITY OF VINES

	Average weight of crop for 4 years	Relative total growth of the vines; no pruning, no crop=100
	pounds	
No pruning, no crop	0	100
No pruning, all crop	51	63
Cane pruning, part crop*	28	69
Normal pruning, all crop	23	65
Severe pruning, all crop	6	64

* Crop regulated by flower-cluster thinning about four weeks before blooming.

Although the nonpruned vines produced an average crop of 51 pounds each year, their bulk was reduced only 2 per cent below that of the normally pruned vines which were producing average crops of 23 pounds, or only 45 per cent as much. The severely pruned vines with a very light yearly crop were limited in growth to almost the same degree as vines receiving the other types of pruning and bearing moderate and heavy crops. In the case of cane pruning the crop was restricted by flower-cluster thinning to what was thought to be its capacity, but it seems that the increase of capacity as a result of the decreased pruning was underestimated; for despite the relatively heavy average crops they produced the greatest total growth of any of the vines with crop.

These figures give some indication of the limiting effect of pruning, as well as of crop, on the capacity of the vine. Crop and pruning (see also table 2) in these experiments apparently diminished the capacity

to about the same extent. With decreased pruning, capacity was increased to such an extent that larger crops with these types of pruning were, if kept within suitable limits by thinning, no more depressing to vine bulk (growth) than were the light crops of severely pruned vines, which had had their capacity greatly reduced by pruning.

2. The production of crop depresses the capacity of the vine. It is generally recognized by grape growers that increase of crop usually follows longer or decreased pruning.[4] The effect of crop, as such, on vine growth, however, has not been clearly understood owing primarily to the fact that under vineyard conditions it is impracticable to separate the effects of crop and pruning. To bring out the effect of crop on growth, several series of vines were treated alike in every respect except crop. In one series of vines (no crop) bearing was prevented entirely by the removal of flower clusters several weeks prior to blooming; in another series (part crop) the crop was restricted by flower-cluster removals to what was thought to be a good crop for the vine; while in a third series (all crop) all of the clusters that were formed were allowed to develop to maturity. Table 4 shows the mean decrease in vine weight due to increases in crop.

TABLE 4

THE EFFECT OF BEARING ON THE GROWTH OF VINES AS INDICATED BY TOTAL WEIGHT

Type of pruning	Alicante Bouschet	
	Average weight of crop (4 crops)	Average total weight of vine (vines 5 years old)
	pounds	*pounds*
No pruning, no crop	0	63
No pruning, part crop	36	35
No pruning, all crop	42	25
Normal pruning, no crop	0	38
Normal pruning, all crop	22	21

The figures of table 4 show that within the limits of this experiment there is a regular falling off in the weight of the vines with an increase in crop. This general relation of crop to growth has been found to hold for older vines also.

The depressing effect of quantity of crop on growth, as indicated by total weight of vine, however, is not the same with the different types of pruning. An average annual crop of 36 pounds during four years on the nonpruned, part-crop Alicante Bouschet vines reduced their weight only 44 per cent below that of the nonpruned, no-crop vines, while an

[4] Bioletti, F. T. Vine pruning in California. California Agr. Exp. Sta. Bul. 241 and 246:29–31. 1921. (Out of print.)

average annual crop of 22 pounds during four years reduced the weight of the normally pruned, all-crop vines 66 per cent below that of the non-pruned, no-crop vines. In the case of the normally pruned, all-crop vines this reduction was only in part due to crop, since these vines also had their capacity reduced by pruning. These figures indicate that vines which have their capacity for growth reduced by pruning (see table 2) are more sensitive to further reduction in growth by bearing than are nonpruned vines. The depressing effect of bearing on growth increases with increased severity of pruning, or, vice versa, it decreases with decreased pruning.

3. The vigor of the individual shoots of a vine varies inversely with the number of shoots that develop. Thus, the fewer shoots permitted to develop on a vine or the arm of a vine the more vigorously (rapidly) each of the individual shoots will grow. For example, on severely pruned Muscat of Alexandria and Monukka vines the number of shoots to a vine that developed was only 22, the average length of shoot was 6.8 feet, while on the nonpruned vines where the number of shoots to a vine that developed was 64 the average length of shoot was 4.2 feet. None of these vines were permitted to produce fruit.

This principle finds special application in the development of young vines. The main object at this period in the life of the vine is to develop a single, strong, vigorous shoot from which to form the permanent trunk.

In a broader application this principle applies to the arms of the vine as well as its fruit. The fewer arms to a vine the more vigorous each will be. Also, if we want large clusters, we must limit their number and if we want large berries, there must not be too many on a cluster.

4. The capacity of a vine varies with the number of shoots that develop. A vine that produces ten shoots of from 3 to 5 feet in length is potentially capable of greater production than a vine with two or three shoots 6 to 9 feet in length. It is the total leaf area rather than the rate of elongation of the shoots that determines the capacity of a vine. A vine with only a few shoots that elongate very rapidly will have a very vigorous appearance, yet its actual potentialities for production are not necessarily so great as that of another vine which, as a result of the development of a greater number of shoots of slower growth, makes no great show of vigor but which because of the number of shoots produces a larger total leaf area. This correlation of capacity with number as well as size of shoots is strikingly illustrated by the figures of table 5.

The figures of table 5 show that although the severely pruned vines produced the longest and most vigorous individual shoots and a crop of only 3.1 pounds of fruit, they made only 85, 74, and 87 per cent respectively as much total length growth as the normally pruned, the non-

pruned part crop, and the nonpruned all-crop vines, despite the fact that these latter vines produced crops which were 3.7, 8.2, and 20.7 times as large respectively. Even the smaller restriction in number of shoots on the normally pruned vines, depressed capacity. This is indicated by the fact that the nonpruned part-crop vines which produced a little more than twice as much crop as the normally pruned vines also produced 15 per cent more length growth than the latter.

TABLE 5

THE EFFECT OF NUMBER OF SHOOTS ON THE CAPACITY OF VINES AS INDICATED BY THE PRODUCTION OF WOOD AND FRUIT

Type of pruning	Number of shoots	Length of shoots, in feet	Total length of wood produced, in feet	Crop produced, in pounds
Severely pruned, with crop	23	5.80	133	3.1
Normally pruned, with crop	33	4.75	157	11.4
Nonpruned, part crop*	48	3.74	179	25.4
Nonpruned, all crop	49	3.18	156	63.5

* Crop regulated by flower-cluster thinning four weeks before blooming.

In the case of the nonpruned all-crop vines capacity was depressed by overbearing which reduced the length growth of the individual shoots. However, the capacity for wood production was almost as great for these vines as for the normally pruned, although they produced over 5.5 times as much fruit.

5. The vigor of the shoots of a given vine varies inversely with the amount of crop it bears. The experience of grape growers generally is that the shoots of vines with little or no crop grow more vigorously than the shoots of vines with medium to heavy crops. The results obtained with our nonpruned Muscat of Alexandria and Monukka vines illustrate this principle very well. The shoots of the no-crop vines made an average length growth of 4.2 feet, the shoots of the part-crop vines with 25.4 pounds of fruit to a vine made 3.7 feet, and the shoots of the all-crop vines with 63.5 pounds of fruit made 3.2 feet. Similarly the normally pruned vines without crop made an average shoot growth of 5.8 feet, while the shoots of the vines with crop (11.4 pounds) made a growth of 4.7 feet.

6. The fruitfulness of the buds of a vine varies inversely with the vigor of its shoots. Within the limits of good commercial practice, methods which increase the vigor of shoot growth diminish the fruitfulness of the buds, and vice versa, methods which reduce vigor favor fruitfulness. Failure to reckon with this fact and to maintain a proper balance between the two extremes leads, on the one hand, to comparative sterility,

and on the other, to overbearing with poor quality of fruit and undue depression of the capacity of the vines. A proper balance is one which maintains a desirable vigor without diminishing the crop.

This relation of vigor to fruitfulness may be illustrated as follows:

Vigor (length of shoots, in feet)	Fruitfulness (clusters to a shoot the following season)
4.2	2.95
4.7	2.45
6.9	1.20

These figures are for Muscat and Alicante Bouschet. It is not intended that this shoot growth be considered as average for locations other than Davis. The average length of shoot under other conditions and with other varieties would differ from these.

With a further reduction in the length of the shoots, which would represent a serious weakened condition of these vines and which would not represent good vineyard management, the fruitfulness of the buds becomes less. In other words, a vine that is seriously weakened by overbearing or by insects and diseases does not have the capacity to form as many flower clusters as a normal vine.

7. A given vine in a given season can properly nourish and ripen only a certain quantity of fruit, that is, its capacity is limited by its previous history and its environment. Too much fruit to a vine results in a product of low sugar and acid content, that is, fruit of very poor quality irrespective of whether or not the cause of overcrop was due to too long pruning, underthinning, shortage of moisture in the soil, disease or insect injury, or some other cause. Furthermore, overbearing not only results in the production of poor fruit, but the capacity of the vine for continued growth and bearing is reduced. Thus every vine must be pruned on its own merits. A vine that has borne heavily or too much must be handled in such a way as to prevent a recurrence of overproduction and premature exhaustion of the vine. The practice among growers has been to attempt to overcome the weakening effects of overbearing by severe pruning which limits the crop of the following season through a reduction in the number of fruitful buds that are retained. This possibly is the cheapest method of guarding against overbearing and the resulting weakening of the vines. However, severe pruning is in itself weakening (see principles *1* and *4*). Thus, the more rational method of guarding against the weakening effect of overbearing would be that of less severe pruning with limitation of the crop by the removal of flower clusters as soon after leafing out as possible or by thinning soon after the berries have set. This procedure not only rehabilitates the vines

faster but brings the action of limitation of crop at a time when the vines are in full leaf; hence a more equitable balance between the leaf surface of the vine and crop can be obtained.

8. The fruitful buds of the vine occur most abundantly on one-year-old canes which arise from two-year-old wood. On the basis of this observation of the fruiting habit of the vine, the pruner should select for fruit spurs and fruit canes, as far as possible, only those canes that were produced the previous season and which arise from two-year-old wood. The buds on the water-sprouts; that is, canes arising from older wood, in some varieties are unreliable. When the development of the water-sprouts parallels that of the shoots arising from the spurs and fruit canes, they will mature their buds and wood well so that they may be suitable for spurs and fruit canes in many varieties. Water-sprouts, however, often arise late in the season and grow rapidly until the end of the season, hence their buds are so poorly nourished that the most of them remain wood buds. Water-sprouts may be used for renewal or replacement spurs on all varieties, since the shoots that subsequently develop on them will have fruitful buds.

Fruitful shoots can arise from older than one-year-wood only on those varieties of which the basal buds (those buds clustered around the base of the cane) are fruitful. In such varieties the basal buds that remain dormant will be fruitful if and when they grow. On varieties of which the basal buds are sterile, shoots but no fruit can arise from the dormant buds.

9. The more erect a shoot, cane, or any part of the vine the more vigorously it will grow. This habit of vine growth is widely employed in the development of young vineyards. In training the young vine the shoot which is selected to form the trunk of the vine is tied to a stake to keep it erect. Experience has shown that this position favors maximum length growth. The vertical position appears to retard the development of laterals, which is no doubt an important factor in the more vigorous growth of erect shoots.

Near the northern limit of vinifera grape growing in Europe where growth, at its best, is small it is regular practice to keep the shoots tied erect that are to be used as fruit canes the following year. The fruit canes are tied down and the shoots arising from them are not supported which moderates their vigor. This system of handling shifts the vigorous growth into the shoots which are to be used for spurs and canes the next year. It increases the capacity of these shoots.

10. The shoots starting farthest from the trunk, other conditions being the same, are the most vigorous. The buds nearest the ends of the canes or spurs usually start growth earliest, which gives them a decided ad-

vantage. To keep the vine within practical limits, this advantage of position must be counterbalanced, especially in the case of long pruning, by measures such as tying horizontally on wires or by twisting and bending, which tend to force the growth of buds nearer the trunk.

Certain defective styles of pruning and handling fail to recognize this tendency, and are therefore impracticable and cannot be continued indefinitely. The commonest of these are half-long pruning and the tying of fruit canes vertically to stakes.

11. Canes with internodes of medium length usually mature their wood best and have the most fruitful buds. Length of internode is an index of the type of growth that the cane has made. The shoots arising at the beginning of the season which make a normal growth will have internodes of medium length for the variety. The fact that a cane has internodes of medium length indicates a good development of its buds and a well-matured condition of its wood.

Long internodes are an indication of excessively vigorous growth which is characteristic of shoots that arise late in the growing season. Such shoots often grow until checked by cold weather and both their buds and wood are apt to be immature. Very short internodes, on the other hand, indicate slow growth which may be the result of poor nutrition or, as is more frequently the case, the result of disease or insect injury or drought.

12. A large cane or arm or vine is capable of greater production than a small one and should, therefore, carry more fruit buds. As has been pointed out, capacity is directly proportional to total growth. A cane of larger size, therefore, has more capacity than a small one. This being the case, a large cane should be pruned so that the spur or fruit cane retained from it will carry more buds than a spur or fruit cane retained from a small cane.

The same is true of arms or vines. If one arm on a vine has large canes and another arm only small canes, more buds should be retained on the arm with the large canes. Similarly a vine with large canes should be pruned so as to retain more or longer spurs or fruit canes than a vine on which the canes are small.

13. Well-matured canes have the best developed buds. The wood of mature canes is firm and carries a large storage of reserve materials, such as starch and sugars. The color of the bark is characteristic for the variety almost to the end of such canes. In the case of canes that are only partly mature the distal part never becomes woody, hence it does not color normally. It usually freezes and dries up before the time for pruning. However, the portion of weak canes that does color may, upon close examination, show areas which have been killed by sunburn or

freezing. Partially immature canes carry only a moderate storage of reserves, while weak canes are very deficient in these materials.

The buds on well-matured canes have the most favorable conditions for development. The length growth of the shoots that form these canes usually ceases well in advance of the end of the growing season, hence an abundant supply of food material is available for the nutrition of the buds. On the contrary, the supply of food materials available for the nutrition of the buds is greatly restricted in the shoots that grow vigorously until the end of the season and which usually form partially immature or weak canes, owing to the demand for these materials for the continued length growth of the shoots.

14. By bending or twisting, the behavior of canes or shoots may be modified for the purpose of regulating growth or fruiting. Experience has shown that the bending of a cane from a vertical to a horizontal position moderates the growth of the shoots arising from the upper buds and augments the growth and fruiting of the shoots arising from the lower part of the cane. The benefit of tying the canes down results from a disturbance of the normal polarity of the cane which favors the growth of the upper shoots on vertical canes. By twisting a somewhat similar effect can be produced; that is, the growth of the shoots arising above the twisted portion is restricted while that of the shoots arising below the twisted portion is augmented. The effect of twisting is, no doubt, the result of a restriction in the flow of materials through the twisted tissues. Since twisting injures the tissues it should be used only with care. It may result in damage.

DORMANT PRUNING

The principal pruning of the vine is done while the plant is dormant, between the fall of the leaves at the beginning of winter and the starting of the buds at the beginning of spring. In large vineyards it may be necessary to spread the pruning over most of this period; in smaller vineyards it is usually possible to prune in the month which the grower may consider most favorable.

Time of Pruning.—In deciding on the best time for pruning, the facilitation of the other cultural operations and its possible effect on the health and bearing of the vine must be considered. Early pruning usually fits in best with the other vineyard operations. Pruning in December or January allows ample time to remove the prunings, to tie the vines and fruit canes, to do the winter cultivation, and where necessary to irrigate before the starting of the buds.

In the past it has been assumed, however, that the time of pruning may materially influence the amount of reserve foods (sugars and

starch) stored in the trunk and roots. This assumption was based on the supposedly rapid translocation of the stored reserves between the above and below-ground parts of the vine. According to Vidal[5] the abundant storage of starch in the canes at the time of leaf fall passed rapidly downwards to accumulate as reserves in the roots. Thus, if the pruning is done immediately after the fall of the leaves, a large part of the reserves in the canes which had not, as yet, moved downward, would be cut off. If this were true, later pruning would avoid the loss of material.

Fortunately the results of more recent investigations on labrusca varieties by Schrader[6] and Richey[7] and work at the California Agricultural Experiment Station on vinifera varieties show that there is no appreciable transfer of starch or sugars from the canes to the roots after leaf fall in the autumn. There is a marked reduction of starch in the canes as winter approaches but this reduction is accompanied by an increase in sugars. Thus, the changes which were observed to occur in the past appear to have been chiefly changes from one form of carbohydrate to another and not a change in the total amount of reserve food. The changes in starch and sugar occurring in the middle of canes of vines during the dormant season at Davis are shown in figure 1. The graphs of this figure together with similar data for the spurs, trunk, main roots, and branch roots support the conclusion that the food materials accumulate as stored reserves in all parts of the vine during summer and fall where they remain without appreciable movement until the following spring when they are partially utilized in the starting of new growth. In the light of these results, it appears safe to say that pruning at any time after leaf fall and before growth starts in spring can have little or no effect on the amount of the carbohydrate reserves of the canes, trunk, and roots of the vine.

The effects of the time of pruning on the vigor and crop of the vine have been investigated by Ravaz[8] in a series of experiments extending over several years, with results which have been in the main corroborated by tests at Davis.

Vines pruned immediately after the fall of the leaves were the earliest to start in the spring. Those pruned when the vines were thoroughly dormant (December to the end of February) started two to six days

[5] Vidal, J. H. Les réserves de la vigne [The reserves of the vine]. Revue de Viticulture 1:895–903. 1893.

[6] Schrader, A. L. Seasonal changes in the chemical composition of Concord grape vines. American Society of Horticultural Science Proceedings 21:39–44. 1924.

[7] Richey, H. W., and H. A. Bowers. Correlation of root and top growth of the Concord grape and translocation of elaborated plant food during the dormant season. American Society of Horticultural Science Proceedings 21:33–39. 1924.

[8] Ravaz, L. Taille hâtive ou taille tardive [Early or late pruning]. 15 p. Montpellier, France. 1912.

later. Pruning when the upper buds on the canes began to swell (late March) retarded the lower buds about four to eight days, and where these buds had grown 2 or 3 inches, eight to fifteen days. Vines pruned in advance of the leaf fall were delayed about ten days in leafing out in spring.

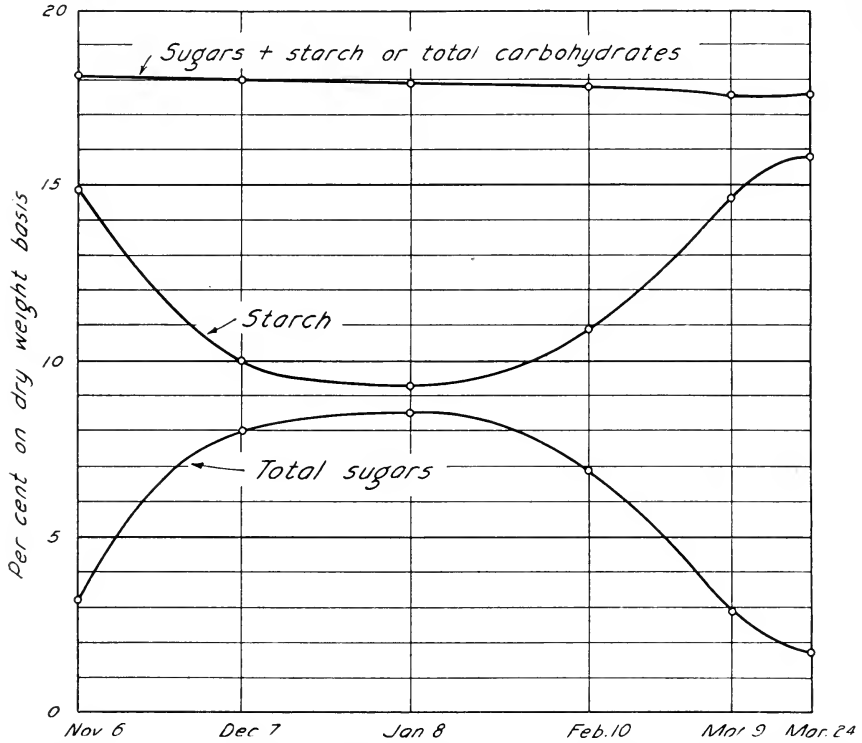


Fig. 1.—Curves showing the change from starch to sugars and sugars back to starch in the canes of the vine during the dormant season, while the total carbohydrates remain almost constant.

Vines pruned before the fall of the leaves are weakened, since this removes the leaves and stops the accumulation of reserves. Otherwise, the time of winter pruning has little if any direct effect on the vigor of the vines. Ravaz noted somewhat greater vigor in vines pruned earliest in the dormant season. This difference in vigor might have been owing to differences in yield rather than time of pruning, since the crop of the vines that were pruned late was slightly above average for the series. Ravaz accounted for this larger yield of the late-pruned vine by their escape from frost. In the Experiment Station tests at Davis the larger yield of these vines appears to have resulted from their later blooming, which increased the probability of warm weather for pollination and setting.

These investigations support the conclusion that time of dormant pruning does not influence the vigor of the vine, except that pruning before the leaves drop is weakening. In frosty locations the pruning may profitably be delayed to near the time of the swelling of the buds or even later so as to take advantage of the later starting which may cause the vines to escape damage from a late frost.

Amount of Pruning.—An average vine before pruning may have 25 canes, with an average of 20 buds on each, or 500 buds in all. Even though the vine is not pruned, all these buds will not start or produce shoots. Probably not more than 40 or 50 will do so. (See table 5.) If we prune the canes back so that we leave only 40 or 50 buds, the same number of shoots will be produced. The only effect will be that buds nearer the bases of the canes will start instead of buds near the ends. (See principle *10,* p. 13.)

If we prune the vine more severely and leave only half this number of buds, a smaller number of shoots will be produced. As this smaller number has a proportionately larger storage of reserves to a shoot as well as the same root system to supply water and soil nutrients, each shoot will grow more vigorously and larger. (See principle *3,* p. 10.) Also a smaller number of bunches will be produced, but each of these may have its flowers somewhat better developed so that although the total weight of the crop will not be so large as on an unpruned or lightly pruned vine it may be of better quality.

To further increase the severity of the pruning, that is, diminish the number of buds left still more, will increase the vigor of the individual shoots at the expense of total growth and crop. There are two reasons for this. One is that very severe pruning decreases size of cluster, since the clusters in the basal buds are small, without a corresponding increase in size of berries. The other is that the excessive vigor given to the shoots is unfavorable to fruiting, often causing coulure or dropping of the blossoms without setting. The pruner should aim, therefore, when crop is controlled by pruning, to leave just enough fruit buds to furnish the number of clusters that the vine can bring to perfect maturity.

Beyond this point the total growth and crop is diminished, quality is reduced and the vigor of the individual shoots correspondingly increased. This increase of vigor is not the direct effect of the pruning, but of the curtailment of the crop, which frees a larger part of the energies of the vine for the work of growth and the building up of tissues. Heavy winter pruning, therefore, invigorates the vine by diminishing the crop. Light winter pruning increases the crop. If this increase is represented by a larger number of clusters than the vine can properly nourish, the crop will be inferior in quality and the vine weakened by overbearing.

On a mature vine which has produced good crops and which is of normal vigor, the pruner should leave the same number of bearing units and fruit buds as was left the year before. If the vine appears abnormally vigorous, more fruit buds should be left in order to utilize this vigor in the production of crop. On the other hand, if the vine appears weak, it should be pruned more severely than the previous year, that is, fewer fruit buds should be left, in order to strengthen the vine by diverting its activities from crop production to building up tissues and replenishing its store of reserve food materials. Or better yet, it may be pruned relatively lightly provided the flower clusters are removed before blooming. This treatment will result in a greater total growth than severe pruning. (See principle *1,* p. 5.) Any attempt to make a weak vine bear a large crop can result only in further weakening of the vine and in the production of inferior grapes. By pruning such a vine for a small crop, or by less severe pruning with limitation of the crop by the removal of flower clusters, the grapes obtained will be of good quality and the vine invigorated so that it can produce normal crops with normal pruning in subsequent years.

Adequate control of crop by pruning alone so that each vine in any vineyard in any and all years will produce a full crop of high-quality fruit and at the same time maintain normal vegetative vigor is impossible. This can be attained only through the use of a method of procedure which retains a sufficient number of buds at pruning to insure the development of an overcrop of clusters in normal years and which depends on thinning in these and the years of greater cluster development to reduce the crop to the bearing capacity of the vine.

Units of Pruning.—When a vine has reached the stage of full bearing, pruning consists in the removal of all the growth except (1) *bearing units,* certain parts for the production of fruit and new wood or fruit only; (2) *renewal spurs,* for renewal or the production of wood for the next year; and (3) *replacement* spurs, in the case of the older vines, for the replacing or shortening of arms. The old fruit canes and the arms to be replaced are removed.

The length of the bearing units is largely determined by the fruiting habit of the variety to be pruned, that is, by the position on the canes at which the fruit buds are borne and by the size of the clusters. On varieties having fruitful buds to the base of the canes, short bearing units are retained. This is called *spur pruning.* On varieties of which the buds towards the base of the canes are sterile (unfruitful) long bearing units must be used in order to secure a full crop. When this is done, it is called *cane pruning.* Occasionally bearing units of intermediate length—*half-long pruning*—are used. Owing to the difficulty of maintaining the

shape of vines so pruned, this method is little used and is not to be recommended. The treatment of a single arm by spur pruning and cane pruning will be employed to illustrate the units of pruning and their use in each method.

The units of pruning in short, or spur, pruning are illustrated in figure 2, representing a long arm about ten years old. At the end of the arm is shown the two bud spur S_2 of the previous year bearing two canes C and C_1. Nearer the base of the arm is shown a single water-sprout WS

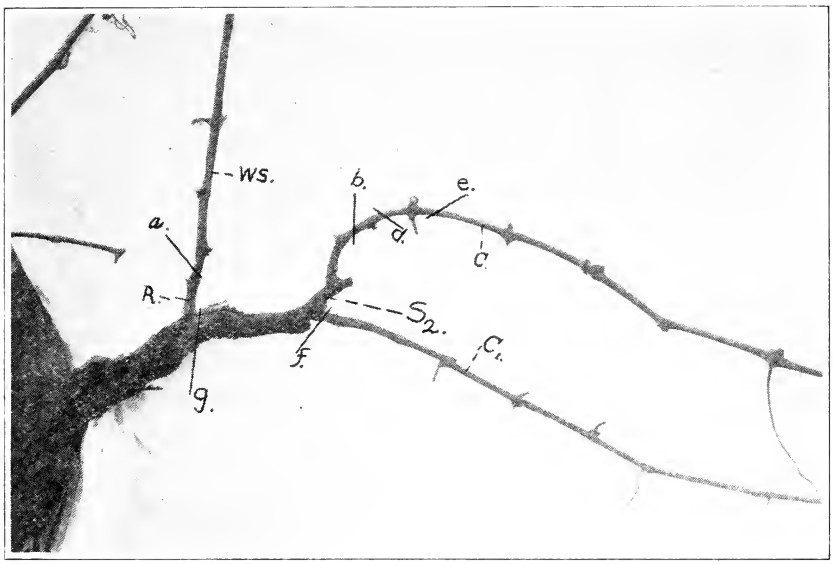


Fig. 2.—The units of short, or spur, pruning. S_2, Two bud spur; C and C_1, canes; WS, water-sprout; R, replacing spur. The lines at a, b, d, c, f, and g indicate the places where vines are to be cut, as explained in the text.

growing out of the old wood. Such an arm would normally bear other canes, but since they would all be removed entirely at pruning they have been removed to simplify the figure.

In pruning such an arm, one of the canes growing out of the spur of the previous year S_2 is cut back to form a new spur for the production of fruit and wood and the other removed entirely. In deciding which cane to use for the new spur, one that is well ripened, of moderate thickness, and with well-formed buds should be chosen. Of those which fulfill this condition, that one must be selected which is in the best position to preserve or improve the form of the vine. This, in most cases, will be the one nearest the base of the spur of the previous year (C_1 in figure 2), because it increases the length of the arm the least. If this one, however, is weak, broken, or its direction of growth unsuitable, as in this case, C or some other cane must be chosen.

When a cane arising from the base bud of the spur of the previous year is chosen for the new spur, the length of the arm is increased imperceptibly. A spur from the first bud C_1 will lengthen it usually little over an inch, one from the second bud C, 2 or 3 inches. In any case, the arm finally becomes too long, like the one in the figure. It must then be shortened or replaced. This can be done by using a conveniently placed water-sprout for a replacing spur, as at R in the figure, and cutting back the arm in the place indicated by the line g.

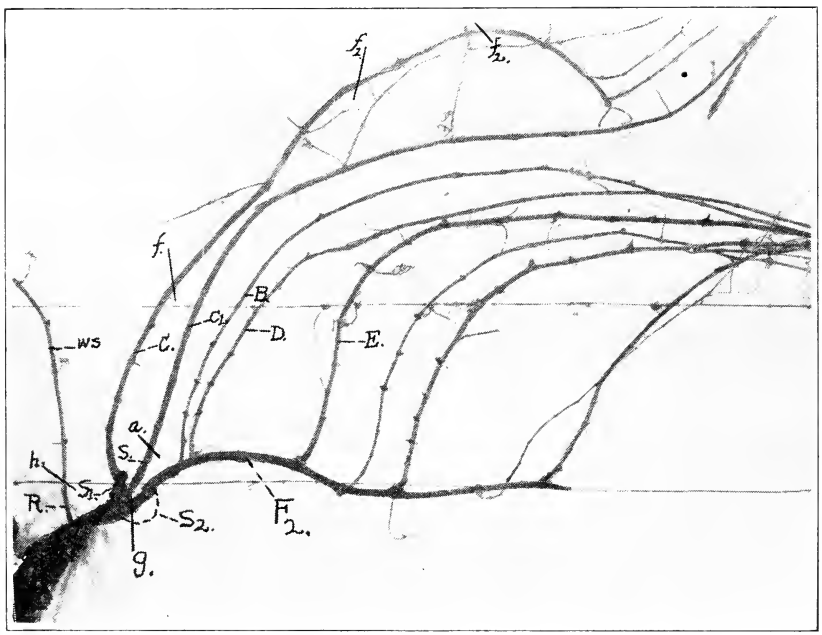


Fig. 3.—The units of long, or cane, pruning. S_1 and S_2, are renewal spurs of one and two years ago and S will be the renewal spur of the coming season; F_2, fruit cane; C, C_1, B, D, and E, canes; WS, water-sprout; R, replacing spur. The lines at a, f, f_1, f_2, g, and h indicate places where vines are to be cut according to different systems explained in the text.

This cutting back of an arm should be deferred until the following year, as the replacing spur on some varieties will produce little or no fruit. In the meantime the fruit spur from cane C will bear a crop and the replacing spur R will produce fruit wood for the following year.

The chosen cane C is cut at b, d, or e, leaving a fruit spur of two, three, or four fruit buds in accordance with its capacity and the fruiting habit of the variety, and the cane, C_1, removed entirely by a cut at f. The more vigorous the variety and the particular cane, the more buds should be left. The water-sprout is cut back at a, leaving a replacing spur of one

bud. Of course, a replacing spur is left only in case the arm is too long and will require shortening the next year.

The units in short, or spur, pruning, therefore, consist of a single fruit spur of one to four fruit buds, and when occasion arises a replacement spur of one bud.

The units of pruning in long, or cane, and half-long systems are shown in figure 3. The spur, S_2, represents the renewal spur of two years previous. On it was left a fruit cane, F_2, which has produced the crop of the past season, and a renewal spur, S_1, which has produced fruit wood for the coming season.

In pruning, the fruit cane F_2 is removed entirely at g. The upper cane, C, of the renewal spur, S_1, is used for a new fruit cane and shortened to about f for half-long and to about f_1 or f_2 for cane pruning. The lower cane, C_1, is cut back at a to form a renewal spur, S, which will produce the new wood for next winter pruning.

This is the normal method of procedure, but various modifications are often necessary. If the cane, C, is unsuitable because of lack of size, other canes such as C_1, or even B, D, or E, near the base of the old fruit cane, may be used for a new fruit cane. In the same way any suitably placed cane may be used for a renewal spur. Water-sprouts from three-year, four-year, or older wood may also be used (R). It is desirable that the renewal spur shall be below the fruit cane, that is, nearer the trunk.

Replacing spurs for shortening the arms are occasionally needed, as in spur pruning, but usually the same spur can be used both for renewal and replacing. The water-sprout, R, may be used for this purpose, cutting it at h.

In cane or half-long pruning then, the units of pruning consist of the fruit cane, the renewal spur, and the replacement spur.

Restriction of and Treatment of Wounds.—The possible length of life of a vine, as far as is known is unlimited. The actual profitable life varies from a few years to fifty or more. Vines may be killed by some disease or unfavorable conditions, such as severe frosts, prolonged drought, etc. Most vines fail and become unprofitable from the effects of an accumulation of small injuries. Among the chief of these are pruning wounds which are not only harmful in themselves by destroying wood, bark, and other conducting tissues, but by allowing the entrance of boring insects and wood-destroying fungi whose effects are much more destructive.

All pruning wounds, therefore, should be made as small as possible, especially in the main body and other permanent parts of the vine. The necessity of making large wounds can be avoided to a great extent by using foresight.

Useless shoots and canes should be removed while they are small and young, and necessary renewals of arms or branches should be made before the part to be suppressed becomes too large. Where large wounds are unavoidable, they should be made as smooth as possible. The vine heals its wounds from the inside by the production of gummy matters or thyloses which fill up the ducts and tissues and so prevent loss of sap. It does not cover the wounds with healing tissue from the outside with the facility that many fruit trees do. Wounds much over an inch or more in diameter seldom heal over completely.

By careful and skillful use of the pruning tools the harm of necessary wounds can be reduced to a minimum. All cuts should be made clean and smooth. This requires that the shears should be kept sharp. If the shears are held at the proper angle there will be no splitting or cracking of the wood. Canes for spurs should be cut at a slight angle, and not at a right angle to the grain. In cutting off a cane or spur entirely the blade of the shear should be placed against the vine and the cut made without undue bending of the part being removed. This will insure a clean, close cut. Stubs left when canes are removed never heal over and they interfere considerably with the making of clean cuts at future prunings. Where large arms or parts are removed a short (¼ inch) stub should be retained.

The cuts at the end of spurs and canes should be made about ½ inch above the last bud. This leaves a sufficient amount of wood beyond the last bud to protect it against drying out and reduces the exposed pith to a minimum. It leaves the woody diaphragm intact to protect the spur from injury. If a long piece of internode is left beyond the last bud a considerable amount of pith is exposed. This exposed pith dries and shrinks to allow water to enter and form an excellent place for molds to grow which may destroy the bud below. Fortunately, injury of this nature is practically unknown in California. In some countries it is recommended that the cut be made through the bud above the last that it is desired to have grow. This leaves the diaphragm intact and leaves no exposed pith. This cut requires considerable skill and practice to cut exactly in the right place; if by mistake, the cut is made just below the diaphragm, the breeding place for fungi has its maximum size.

Disposal of Prunings.—Although the pruning brush has no particular fuel, feed, or fertilizer value, its influence upon the texture of the soil has in many instances been found of great value. The prunings improve the soil texture more as the soils become heavier and tighter. Very light open soils benefit little from them. In view of the value of the prunings as a soil addition, the practice of incorporating them into the soil is becoming more general. A heavy (covercrop) disk is usually satisfac-

tory for reducing the prunings in size and covering them with soil. Where this does not reduce the size of the pieces of brush sufficiently to facilitate the other cultural operations, the brush may be passed through a brush shredding machine. The shredder is powered from and drawn through the vineyard by a tractor. It takes the brush from the ground if it has been placed in the middle between the rows by the pruners. When it is impractical to return the prunings to the soil directly, they may be burned in a brush burner in the vineyard or raked or hauled to open places adjacent to the vineyard for burning.

SUMMER OR HERBACEOUS PRUNING

Summer pruning, of which there are many forms, consists in the removal of buds, shoots, or leaves while they are green or herbaceous, and is done, therefore, while the vine is growing or active.

The effects of summer pruning are in some respects similar to those of winter pruning and in some quite the opposite. If we remove a part of a cane in the winter, we weaken the vine by diminishing its latent possibilities of growth, yet indirectly this weakening effect is offset to a considerable extent by diminishing bearing. If we remove a growing shoot in the summer, on the contrary, we weaken the vine because we remove leaves, which are its principal manufacturing organs and to which it owes its vigor and capacity. This weakening effect is greatest in the middle of summer when the vine is most active and most in need of the food supplied by the leaves. The removal of all the leaves by defoliating insects at this time may kill the vine. The danger is not so great early in the spring before the reserve food materials stored in the vine the previous season have been exhausted. At this stage a certain number of shoots or a considerable number of leaves can be removed without serious injury. In fact, vines struck by spring frosts are often more vigorous, because the weakening due to the removal of leaves is more than counterbalanced by the strengthening due to the smaller number of shoots that develop and to the lack or restriction of the crop.

The removal of growing shoots or parts of shoots also has an effect similar to that of winter pruning, that is, the concentration of the growth of the vine in the parts retained. This concentrating effect and the weakening effect occur, in inverse ratio, and vary according to the time of pruning. In early spring, at the starting of the shoots, the weakening effect is very slight and the concentrating effect almost as marked as that of winter pruning (see principle *3*). In early summer, with the vines in full growth, the weakening effect may be sufficient to completely neutralize the concentrating effect, that is, the removal of some of the

shoots may so weaken the vine that there will be no acceleration of growth in those which are left. Still later, the weakening effect may exceed the concentrating effect, and the shoots which are left will make less growth than if none had been removed.

Uses of Summer Pruning.—Summer pruning has various uses, of which the principal are:

1. To direct the growth into those parts which are desired to form the permanent framework of the vine, such as the trunk, branches, and arms, and to maintain these parts in an active healthy condition. This is accomplished by such operations as disbudding, pinching, and suckering.

2. To alleviate wind damage by pinching. This checks length growth temporarily and allows the basal portion of the shoot to become hardened and tough so that it is less easily broken off.

3. To increase the shade on the fruit by topping or pinching to promote an upright position of shoots and the growth of laterals.

4. To open up the vines so as to expose the fruit more favorably to light and air.

Disbudding.—This is practiced on young vines during the development of the vine. It consists in removing the swollen buds and young shoots from the lower part of the stem of the vine in order to concentrate the growth in one or more shoots which are used in developing the trunk, branches, or arms of the vine. By this operation the production of canes low down on the trunk and the wounds made by cutting them off the following winter may be avoided. The sooner the young shoots are removed the better. Early removal prevents their using up much of the reserves of the vine and comes when the concentrating effect of their removal is at its maximum. On younger vines which have not yet formed a stem, it consists in removing all the buds and young shoots but one in order to concentrate all the growth into a single shoot which is to form the stem or trunk of the vine.

Late disbudding, that is, when the young shoots are more than 3 to 6 inches long is more appropriately called *shoot thinning.* It is inferior to disbudding, in that it is more weakening to the vine and the concentrating effect is correspondingly less.

Topping Young Vines.—When by disbudding during the second year all the growth has been concentrated into a single shoot this shoot will grow with great vigor. When it has grown 6 to 10 inches above the top of the stake, that is, above the height at which it is intended to develop the head, it should be topped. This topping has the effect of forcing the growth of laterals. These laterals may be used at the following winter pruning as fruit spurs and as the beginning of permanent arms. If this

topping is not done, there may be very few buds on the mature cane in the region at which it is desired to make the head. It will, therefore, be difficult to find buds in the proper place for the development of the arms and to produce the crop of grapes which the vine should yield during the third season.

Suckering.—This is the removal of all shoots which originate at or below the surface of the ground. Neglect of suckering results in diminished vigor of the whole aboveground portion of the vine. The suckers bear little or no fruit, hence grow vigorously and appropriate the sap which should nourish the whole vine. Finally, the top may die, the whole growth go into the suckers, and all the benefits of a properly shaped vine will be lost. Such a vine can be renovated only by cutting off the old stump and building up a new vine from a vigorous sucker.

With grafted vines the consequences are even more serious. The suckers, coming from the stock, take the sap even more easily from the top, since the top is connected to the root by the grafting union which impedes the passage of water and food materials to the top. A grafted vine which has been seriously weakened by the prolonged growth of suckers is useless and cannot be renovated.

Suckering should be done with the greatest care and thoroughness during the first four or five years. This will save a great deal of expensive and troublesome work later. Very few suckers will be produced by vines which have been properly cared for in this respect during the first three years, and such vines will usually cease to produce any after five or six years. Vines on which the suckering has been imperfectly done during the first three years, on the contrary, will always produce an abundant crop of underground shoots every year.

Suckering, like disbudding, should be done as early in the season as possible for the reasons already given. Another and even more important reason is that suckers which are removed late, and especially those which are allowed to grow the whole summer, promote the formation of buds which may remain dormant and of tissue which readily forms adventitious buds below ground.

It is necessary to sucker young vines two or three times during the spring. This is done every time the vines are visited for hoeing or tying up. When the suckers are soft and succulent they are easily pulled off without cutting. They must be removed completely at the base. When they get a little tough it is necessary to dig down to their point of origin for this purpose. To remove a sucker partially is worse than useless. The part which remains forms an underground spur or arm which will be a source of perennial trouble.

Crown Suckering.—This is the removal of shoots in the crown or head of the vine, especially the water-sprouts. Crown suckering is advisable when it is done to prevent growth in places where growth is not wanted, to open the head of the vine to improve the quality of the fruit, or to concentrate growth in parts where it is wanted. The removal of sterile shoots in all cases, on the theory that they are useless, however, is a mistaken practice.

The growth of a large number of water-sprouts or the production of many sterile shoots is usually a sign that the full vigor of the vine is not being used for the production of the crop or that the method of pruning is incorrect. The cure for this is longer pruning, or the use of a type of winter pruning which is better adapted to the fruiting habit of the variety. The production of sterile shoots on what ought to be fruit wood often indicates some cultural error which results in excessively vigorous growth or too late growth of the vine in autumn.

Sterile shoots are by no means completely useless. The foliage they produce nourishes the vine and makes it more capable of bearing fruit. They may be needed for use as bearing units, renewal spurs, or replacing spurs, for which purpose, owing to their position, they are often better than fruitful shoots.

Water-sprouts are sometimes troublesome by growing through the clusters, making it impossible to harvest the crop without injury or by making the head of the vines too dense. This is particularly harmful with table grapes. By removing the undesirable shoots early in the season while they are small, this trouble may be overcome for the season. Their removal at that time will not weaken the vine. Care must be used not to remove too many shoots directly over the crown of the vine. The exposure of the large branches and arms to the direct rays of the sun in the hotter regions during midsummer when the relative humidity is very low will result in injury, causing the trouble sometimes referred to as "bald-headed" vines.

The tendency of water-sprouts to grow through the clusters may be more or less permanently overcome by modifying the shape of the vine at the winter pruning so as to allow all the clusters to hang free. Improvement may also be obtained by a better balance between capacity to produce and the crops of the following seasons.

Pinching.—This consists in the removal of the growing tip of a shoot with thumb and finger. Its weakening effect is very slight, since no expanded leaves and a very little material are sacrificed. Its immediate effect is to arrest the elongation of the shoot. If this is done when the shoot is 15 to 18 inches long, the shoot has time to become sufficiently

tough to resist the wind before it gets long enough to afford the wind much pressure surface. Shoots pinched as early as this usually produce a new growing tip from a lateral which later cannot be distinguished from an original growing tip. Later pinching usually causes the growth of several strong laterals.

It has often been reported that the pinching of fruiting shoots, just before blossoming, tends to make the fruit set better. Reports to the contrary are also numerous. Results obtained at Davis support the latter. Under certain favorable conditions pinching may possibly tend to overcome coulure. However, its regular use in this connection is questionable.

Topping Bearing Vines.—This consists in removing 1, 2, or more feet of the end of a growing shoot usually in June or July or later. In some regions topping is practiced regularly twice or even three times during the season. In general, it is used more in the cooler districts.

If practiced early, it has much the same effect as pinching. It tends to keep the canes upright and to cause the development of laterals. It involves the removal of full-sized leaves and is therefore weakening. In very windy districts it may be an advisable practice, for it is better to cut off part of the shoot and save the remainder than to have the wind break off the entire shoot. The later the topping is done the more leaves are removed and the more weakening the practice is to the vine. Constant severe topping may have a serious effect on the vigor of even the strongest vines. It always decreases the crop. Topping three times at Davis[9] diminished the crop of Tokays by 32 per cent and of Carignanes by 42 per cent.

Both pinching and topping are used frequently with the object of protecting the fruit from sunburn, by increasing the shade for the grapes. For this purpose heavy pinching is much superior to topping. When a shoot is allowed to grow without interference it takes at first a more or less upright direction. As it increases in length its weight tends to bend it over to a more or less horizontal or downward direction. With some rapidly elongating varieties, the shoots bend over and take a reclining position, resting for a considerable portion of their length on the soil. With nearly all varieties they will finally bend outward and downward sufficiently to open up the center of the vine to the sun.

In many cases this opening up of the center is an advantage, promoting the coloring of the grapes and making easier the control of mildew. In some it increases the sunburn of the grapes. Sunburn, however, is not due alone to the direct rays of the sun, since some clusters completely

[9] Bioletti, F. T., and F. C. Flossfeder. Topping and pinching vines. California Agr. Exp. Sta. Bul. 296:371–384. 1918. (Out of print.)

exposed do not sunburn and others much shaded do. The commonest form of sunburn is due to an excess of evaporation over sap supply. If more water is lost through the skin of a grape than is supplied through the stem, it will dry up. An excess or a deficiency of water in the soil may curtail the sap supply and sunburn will result. Large crops greatly increase the need for water, hence sunburn is worse on vines with heavy crops. Defective or diseased stems or roots, and large wounds on the stems or arms may have the same effect. Increasing the shade, therefore, is merely a palliative, and any method which weakens the vine will increase the trouble.

If the growing shoots are pinched once or twice before they are 3 feet long, the shade is increased in two ways. First, they grow more upright as they are relieved from the weight of the growing top until they are sufficiently lignified to retain their upright position. Second, they produce laterals which increase the number of leaves near their base and over the head of the vine. Topping, being done later, is less effective in these respects, and moreover, as it involves the removal of feeding leaves the vine may be weakened so much as to increase the trouble.

Defoliation.—The coloring of certain varieties of grapes can sometimes be facilitated by opening up the vines to permit the air to move through them more freely. One of the means of doing this is by removing the leaves. If the removal of leaves is delayed until the fruit has attained the minimum sugar content desired, little or no harm will be done to either the vine or fruit, while the coloring and color of the fruit may be greatly improved. Should leaves be removed before the fruit reaches the minimum sugar content for harvesting, its maturing as well as the development of color will be retarded. For this purpose only the leaves in the head of staked vines and those on the lower part of the north or east side of trellised vines should be removed. The number of leaves to be removed depends on the size and vigor of the vines. The removal of one-eighth to one-third of the leaves will usually give the desired results. To remove more leaves will greatly weaken the vines and may stop the development of the fruit.

Removal of the interior leaves may be useful in some cases, with very late varieties, to protect them from molding after rains. It allows sun and air to reach the grapes freely and helps to evaporate the moisture quickly from their surfaces.

"Sheeping" the vineyard, or allowing sheep to eat the leaves immediately or soon after gathering the crop of early maturing varieties, is undoubtedly a bad practice. It removes the leaves before they have fulfilled their important duty of providing the reserve food to be stored up in the canes, trunk, and roots for the growth of the following spring.

THINNING

The removal of flower clusters before blooming and of clusters or parts of clusters after the fruit has set is called "thinning." Like pruning it consists in the removal of living parts of the vine and like pruning it concentrates the activities of the vine into the parts left. In other respects, however, the effect of thinning is quite the opposite of that of pruning—it strengthens the vine by limiting the crop without diminishing the actual or potential leaf area. Thinning offers far greater possibilities in the improvement of quality than does pruning. This is owing to the fact that the regulation of crop by thinning is done when the vine is in leaf, hence a better balance of capacity and crop is possible, because the character of the fruit can be materially improved by thinning. The regulation of crop by thinning merely consists in limiting the crop sufficiently by removals so that the vine is capable of developing perfectly what is retained. The choice of the method of thinning to be employed depends entirely on the type of fruit a variety produces; that is, whether it is desirable to retain the character of the clusters as they normally develop, or to change their character with respect to size, shape, or density. The utility or advantages of the different methods of thinning for the purposes just referred to can be best shown by a discussion of the methods of thinning and by indicating the time at which each is carried out and how it influences the character of the fruit.

Flower-Cluster Thinning.—The clusters of rudimentary flowers of the grape come out with the leaves when growth starts in spring. The parts of the individual flowers, such as the pistil, anthers, petals, and sepals are formed after leafing out and develop up to the point of blooming in from six to eight weeks, according to the season. Now, if some of the flower clusters are removed early in this period, between leafing out and blooming, without disturbing the number of leaves on the vine, the retained clusters have a larger number of leaves to nourish them. With the increase in the ratio of leaves to flower clusters the flowers are better supplied with the food materials—carbohydrates—that are manufactured in the leaves. As a result of the more abundant supply of carbohydrates, the flower parts develop more perfectly, with a consequent better set of berries and an increase in the percentage of normal berries.

The usefulness of flower cluster thinning in the improvement of quality, therefore, is limited to varieties that have loose or straggly clusters or that set shot berries, or both, with the usual pruning. These difficulties will be most successfully overcome when this type of thinning is carried out as soon as possible after all the flower clusters have appeared so as to obtain the maximum influence of the improved nutrition on the re-

tained clusters. The proper stage of development for flower-cluster thinning is shown in figure 4. The earlier the thinning, as long as all of the clusters are out, the less expensive it is, since fewer of the clusters are obscured by the leaves.

This method of thinning should be used when longer pruning with thinning is employed to rehabilitate weakened vines. For this purpose most if not all of the flower clusters should be removed.

Fig. 4.—A single cane of a Muscat vine showing the proper stage of development for flower-cluster thinning. (From Bul. 519.)

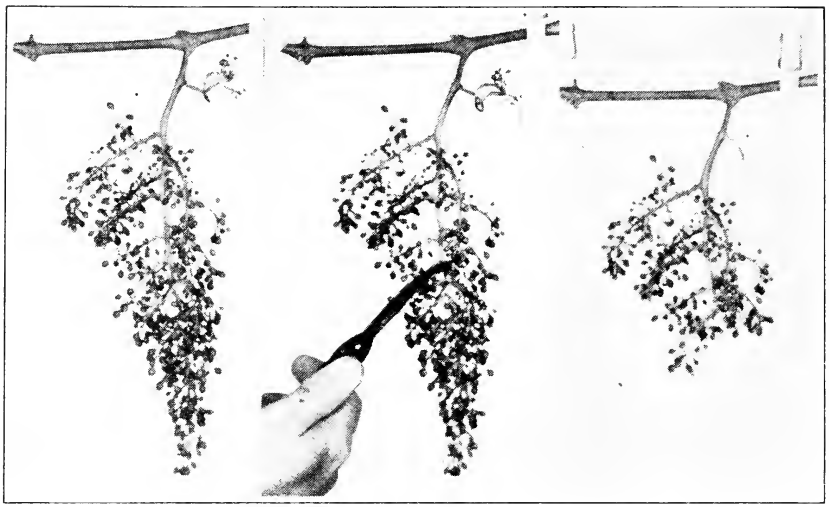
Cluster Thinning.—Cluster thinning means the removal of clusters after blooming, that is, after the berries have set. As it is not carried out until after blooming, it does not influence the number of berries to a cluster, and since entire clusters are removed it does not change the character of the retained clusters. Its usefulness in the improvement of quality, therefore, is limited to varieties that set well-filled clusters. This method of thinning results in an improvement in quality primarily through its influence on uniformity in size of cluster, size of berry, and coloring. The greater uniformity results from the removal of oversize, undersize, and misshapen clusters. Cluster thinning should usually be carried out as soon as all of the berries that will set have done so. The stage of growth at which cluster thinning should be done is shown in figure 5. The early removal of undesirable clusters improves the conditions of nutrition for the retained clusters and hence the fruit will develop better. This is especially important as regards the increase in size of berry. Early thinning also prevents the wasting of energy by the vine in the development of clusters which are to be removed. If done skillfully and with discretion not only is the quality of the fruit improved but the crop is not diminished.

Berry Thinning.—As used in California berry thinning consists in the removal of parts of the cluster. It usually consists in cutting off the end of the main stem and several branches of the cluster or in cutting off a sufficient part of the main stem so as to retain only the desired number of berries.

Fig. 5.—A long-pruned vine showing the proper stage of development for cluster thinning. (From Bul. 519.)

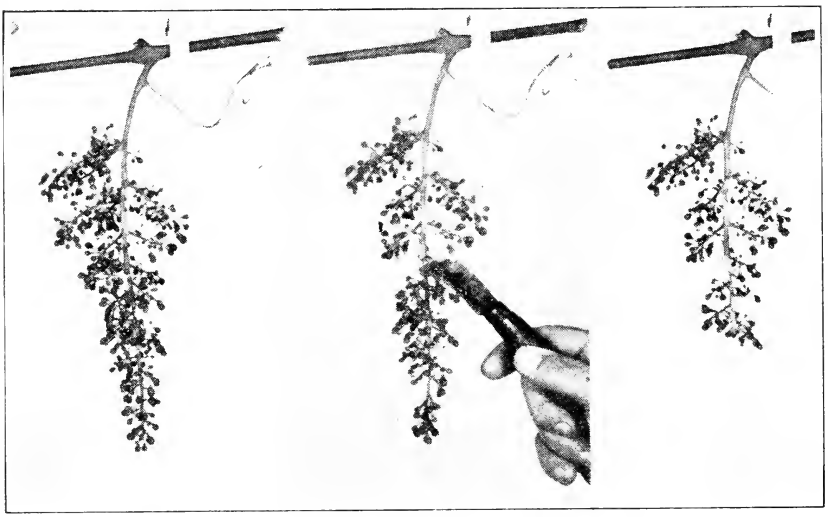
Berry thinning can improve quality only when the berries are so numerous as to make the clusters too compact to be of high quality or when the cluster parts are so large as to interfere with proper coloring and maturing. Its usefulness in the improvement of quality, therefore, is limited to varieties that set very compact or very large clusters. Berry thinning usually changes the character of the cluster materially. It always reduces their size and may alter their shape.

Berry thinning should be done as soon as possible after the drop of berry forms that normally follows blooming is complete. Thinning at this stage of development results in maximum increases in size of berry. When the thinning is delayed 8 to 10 days the gain in berry size will usually be about one-third less; and when delayed 15 to 20 days it will be two-thirds less. The proper stages of development for berry thinning together with different methods of thinning are shown in figures 6, 7, and 8.



A *B* *C*

Fig. 6.—A method of berry thinning adapted to clusters with large shoulders, such as cluster *A*. *B*, The shears placed for cutting the *main stem* of the cluster; *C*, the thinned cluster.



A *B* *C*

Fig. 7.—Berry thinning by which *the branches along one side*, except the uppermost branch of the main stem, are removed and the end of the cluster shortened back. This method is adapted to long, narrow clusters, such as the cluster *A*. *B*, the act of thinning, using a knife; *C*, the thinned cluster.

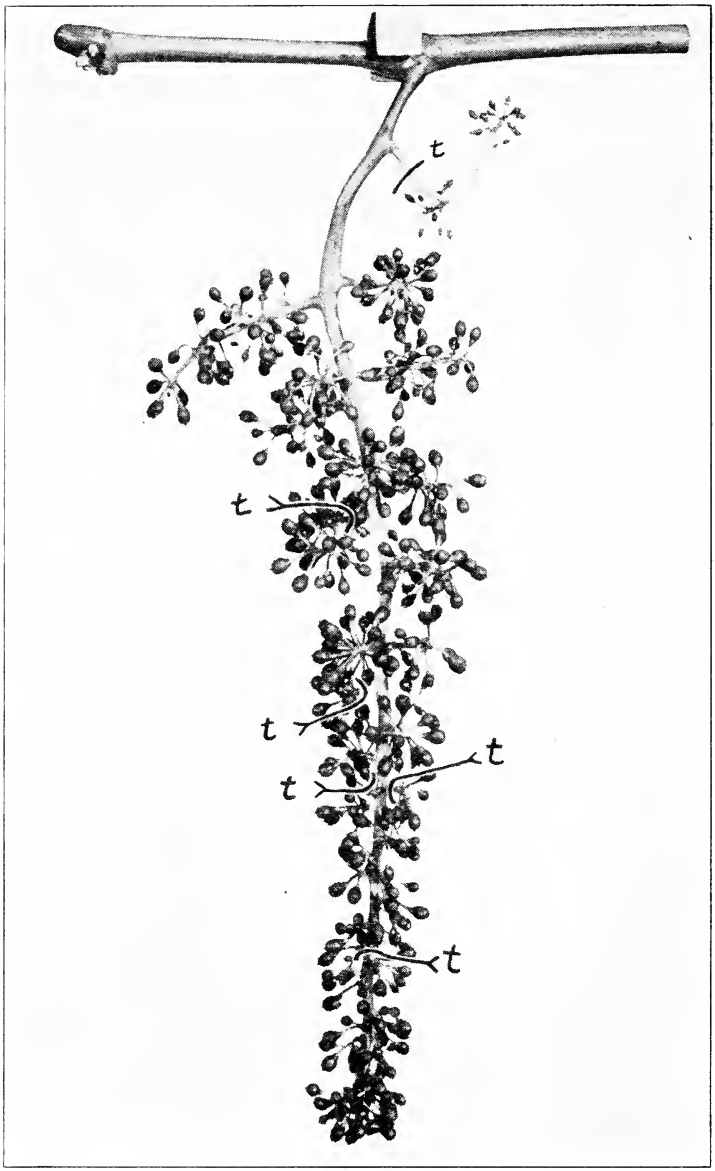


Fig. 8.—Another method of berry thinning adapted to long, narrow clusters. This method retains the normal shape of the cluster. The positions at which cluster parts would be removed are indicated by the curved lines marked *t*.

CLASSIFICATION OF PRUNING SYSTEMS

The systems of pruning applied to the vine are innumerable. They differ in the form given to the body of the vine and in the number and length of the pruning units retained. Some of the differences depend on variations in the nature of the vines, on the cultural and growing conditions of the district, and on the objects of the grower. Others are unessential and merely a matter of taste. The best system is that which is most adapted to all the conditions of the particular vineyard. Any system which does not take into account the nature of growth and the fruiting habit of the vine is defective.

Although the number of pruning systems is large, the essential differences are few. On the basis of these differences the systems of pruning may be classified according to: (1) the arrangement and amount of old wood, (2) the length of the units of bearing wood, and (3) the management and placing of the bearing units. According to the arrangement and amount of the old (permanent) wood, the systems of vine pruning may be divided into two groups. In the systems most commonly used there is a definite head to the trunk, from which all the branches or arms arise symmetrically at nearly the same level. The vines of these systems may be called "headed vines." The systems of head pruning and cane pruning as used in California, the Guyot system, the Goblet system, the Medoc system, and similar systems used in the various grape-growing countries fall in this group. In the other group the trunk is elongated 5 to 10 feet or more and the arms are distributed regularly along the whole or the greater portion of its length. The vines of these systems, owing to the rope-like form of the trunks, are called "cordons." The vertical and unilateral and bilateral horizontal cordon systems as used in California, South Africa, Australia, and similar systems used in the other grape-growing countries are representatives of this group.

The headed vines are classed according to the length of the vertical trunk into high, 3 to 6 feet; medium, 1½ to 3 feet; and low, 6 inches to 1½ feet. In the case of headed vines which are trained on arbors, the trunk may be 6 to 8 feet long. The arrangement of the arms of a headed vine may be symmetrical in all directions and rising upward at varying angles from very small to about 45 degrees. This or modifications of this form are used in the great majority of vineyards whether of wine, raisin, or table grapes. It is suitable for the "square" system of planting and cross-cultivation. Where vines are planted in the avenue system, particularly when trellised, and where cross-cultivation is impossible, the arms are given a "fan-shaped" arrangement in the plane of the trellis.

This arrangement is essential for the economical cultivation of trellised vines.

The cordons may be vertical or horizontal, according to the direction of the trunk. The horizontal cordons may be single (unilateral) or com-

Fig. 9.—The fruit canes placed on both wires of a two-wire trellis. Note the tendency of the arms to become long and the absence of renewal wood on the head of the vine.

Fig. 10.—The fruit canes tied individually on separate wires of a wide-top trellis.

posed of two branches extending in opposite directions (bilateral). Double and even multiple vertical and horizontal cordons occur, as in the Espalier system. These not only have no advantages in the commercial vineyard but are inadvisable. On the vertical or upright cordon

the arms are arranged at as regular intervals as possible on all sides of the trunk from the top to within 12 or 15 inches of the bottom. On the horizontal cordon the arms are spaced at regular intervals, but as nearly as possible on the upper side only of the horizontal part of the trunk.

Each of these systems of pruning may again be divided into two systems according to the length of the bearing units. In the most severe types of pruning the canes retained for bearing units are cut back to one and two bud spurs. This is called "short spur pruning." In long spur

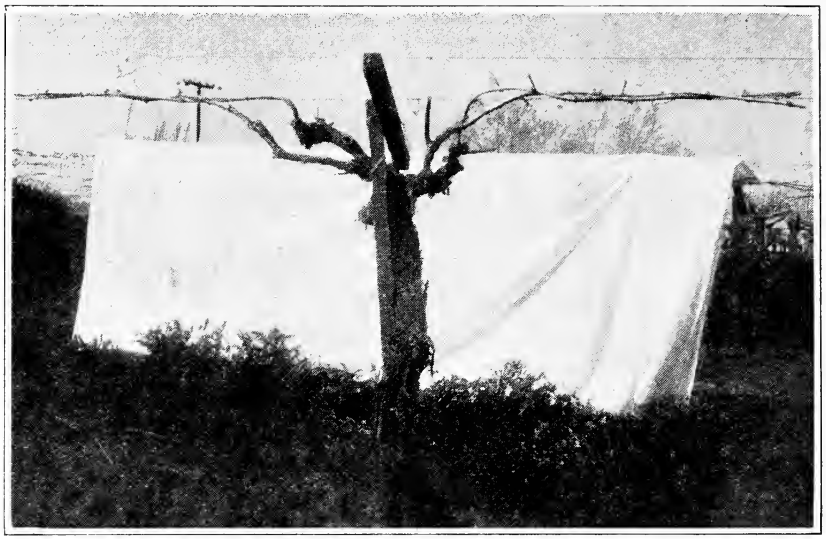


Fig. 11.—The fruit canes tied to the middle wire of a three-wire wide-top trellis.

pruning the bearing units are three to four bud spurs. In the other systems long canes are left for fruit production. This is called "cane," or "long pruning." In rare cases an intermediate form is adopted in which short or half-long canes of from five to seven eyes are left. In cane pruning, each fruit cane is usually accompanied by one or two short renewal spurs. These must also accompany half-long pruning. Systems of pruing, where only long canes are left without renewal spurs, are usually defective in that they make it impossible to maintain a desirable form of the vine. In all systems replacing spurs are left wherever and whenever needed.

In the case of long pruning the management of or the position given the bearing units varies greatly. The differences depend on variations in the cultural and growing conditions of the grape-growing regions and on the type of support used.

In California where a two-wire trellis is used the canes are distributed

equally in the two directions of the trellis from the vine. The recommended practice is to tie all of the canes to the lower wire, using the upper wire only as a support for the shoots (fig. 18). Many growers, however, distribute the canes uniformly on both wires (fig. 9). This method distributes the fruit more, but the fruit of the canes on the

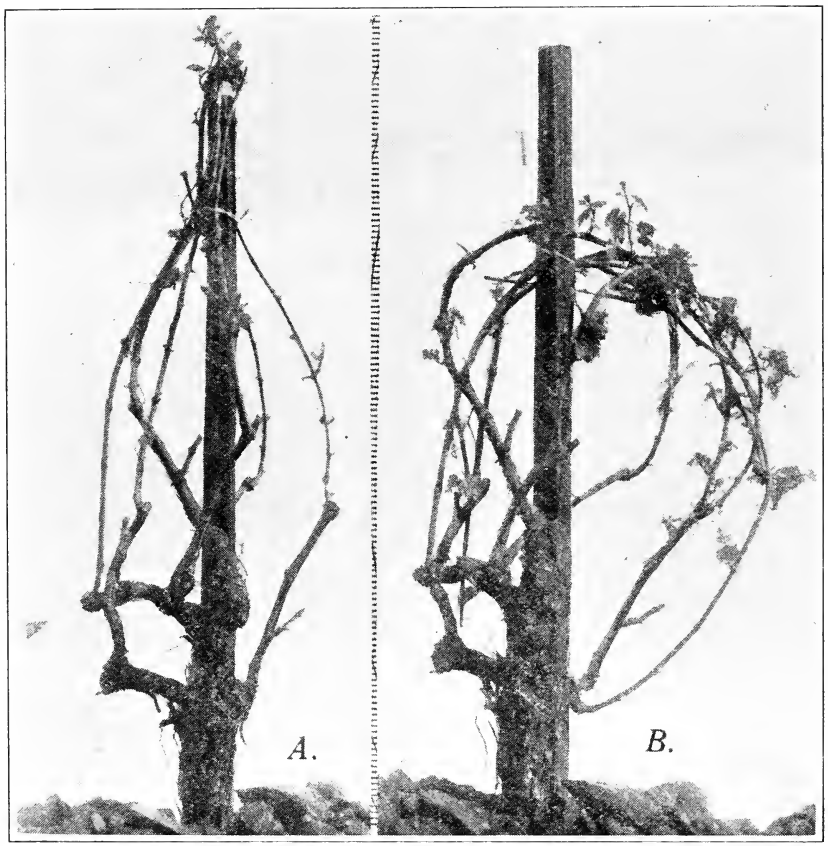


Fig. 12.—Forms of cane pruning: *A*, the fruit canes tied vertically; *B*, the fruit canes tied in a bow over the head of the vine.

lower wire is shaded more densely than that of the canes on the upper wire. The difference in exposure of the fruit may interfere with the uniformity of its development, especially the coloring of table grapes. Where this method of distributing the canes on both wires is used the head of the vine should be just below the upper wire, so as to favor the growth and development of the shoots arising from the renewal spurs. If the head is low, the renewal spurs are certain to be shaded and often fail to develop canes suitable for use as fruit canes the following season. With the wide-top trellis the canes are usually spaced evenly by tying

only one cane to a wire which distributes and exposes the fruit uniformly (fig. 10). In some cases the canes are placed on the middle wire of a three-wire wide-top trellis (fig. 11).

With vines that are only staked the canes are tied vertically to the stake (fig. 12*A*) or they may be bent in a circle with their middle tied to the stake and the upper end supported by tying to other canes or to the arms (fig. 12*B*). Both of these systems are defective in that the most vigorous shoots develop from the highest parts of the canes and thus shade out the renewal spurs. In these systems the yields are small and the fruit is nonuniform owing to the crowding together of the clusters by this manner of tying.

COMMERCIAL SYSTEMS OF PRUNING

The various systems of pruning vines used extensively in practice may be grouped into three general types for which *head pruning, cordon pruning,* and *cane pruning* are convenient names. There are various subtypes under each of these general types, each of which has advantages for special conditions. The first two of these general types and their subtypes, on which the retained annual growth is usually reduced to spurs, are distinguished by the form that is given to the more or less permanent parts of the vine. The third general type and its subtypes, on the contrary, take their name from the bearing unit—the fruit cane—and the position of the bearing units on the supports.

HEAD PRUNING

In the systems of pruning of this group the vine is given the form of a small upright shrub (fig. 13). The mature vine consists of a vertical stem or trunk bearing at its summit a ring of arms or short branches ascending in the form of a vase or hollow inverted cone. At the end of these arms, at each winter pruning, are left the spurs consisting of the basal portions of canes which are the matured shoots that grew during the previous summer. These spurs produce shoots which serve the dual purpose of bearing the next crop of fruit and supplying wood for next year's spurs. Thus, this system consists of head training and spur pruning. The point or region at which the trunk divides into or bears the arms is called the "head."

This type of pruning is often spoken of as "vase" or "goblet" pruning. The vase-formed arrangement of the arms, though usual, is not universal nor essential, hence the term "head pruning" seems preferable. In regions of very high temperatures and low relative humidity the head of

the vine may be sunburned if the vase arrangement of the arms permits the rays of the sun to shine directly upon the base of the arms. Under such conditions sufficient growth should be maintained directly above the head to shade this part of the vine.

Pruning Mature Head-Pruned Vines.—With a mature head-pruned vine sufficient spurs should be left to obtain a full crop of fruit of high quality, and still maintain the vigor of growth of the vine and its form.

Fig. 13.—A mature head (spur) pruned vine.

The number of buds left should be in proportion to the capacity of the vine, and they should be distributed on the spurs in proportion to the size of the canes which were cut back to form the spurs. The spurs should be so distributed that the form of the vine will be maintained or improved and the fruit will be uniformly exposed.

The number of buds or spurs to leave on a mature vine can be most easily determined by roughly counting those that were left the previous year and by observing the size of the canes. A vine that produced a good crop of fruit and on which the canes are of normal size, should be pruned

so as to leave the same number of buds and spurs as were left the year before. If the canes are abnormally large for the variety, indicating that they were very vigorous the previous summer, more buds should be left in order to utilize this capacity in the production of fruit. More buds may be left by either increasing the length of the spurs or by increasing the number of spurs. The method selected to increase the number of buds should be the one which best retains the desired form of the vine and which will also distribute the fruit uniformly. On the other hand, if the canes appear weak, that is of small size for the variety, fewer buds should be left. To reduce the number of buds the number of spurs retained may be reduced or the spurs may be cut shorter. In every case the spurs retained from large or vigorous canes should carry more buds than those retained from small or weak canes.

What has been said above applies to those varieties which produce regular and full crops with head pruning. If the crops of the previous years have been small and the vine growth large, it might indicate that the basal buds of the variety are not very fruitful. In such a case the spurs should be left longer. If this does not result in the production of full crops it may be necessary to try some type of cane pruning.

Advantages of Head Pruning.—The advantages of head pruning are simplicity of form, ease of training, and cheapness. The headed vine is the easiest type to establish largely because of its relatively short trunk and the small amount of permanent wood in comparison to that of the cordon type. The fact that the trunk is upright over its entire length also simplifies the training.

Headed vines are usually relatively small, hence the cost of supports is relatively low. Stakes are necessary during the development period, but the trunks or stems become sufficiently rigid to be self-supporting after five to eight years. This type of support permits cross-cultivation when the vines are planted at about the same distance in both directions. This may be an advantage when the control of noxious weeds is a problem.

Disadvantages of Head Pruning.—Head pruning allows the least development of the vine, hence it is the most depressing. When crop is controlled entirely by pruning, as is the usual practice with most head-pruned varieties, the pruning must of necessity be severe in order to prevent overbearing. With this type of pruning the vines remain relatively small and capacity for both growth and production is depressed.

The necessity of pruning to relatively short spurs not only reduces the capacity of the vine, but also tends to keep the head too compact. The fruit may be of inferior quality owing to its unequal exposure to light

and air. As the vines become old and the arms longer, this defect is less serious. Long spur pruning with some form of thinning to regulate crop helps to overcome the tendency to crowd the fruit and lessens the depressing effect of the pruning.

In some varieties, notably the Muscat of Alexandria, the fruit is poor as a result of coulure (shelling) and the setting of shot berries. Pruning investigations at the California Agricultural Experiment Station have shown a definite relation between these troubles and the restriction of leaf development early in the season with this type of pruning.

Fig. 14.—A mature, horizontal bilateral cordon-pruned vine.

With still other varieties the crops are small and irregular with head pruning owing to the fact that the buds towards the basal end of the canes are not always fruitful. Slight variation in the fruitfulness of the buds of a single variety may occur from year to year which may in some instances account for irregular bearing. Long spur pruning with some form of thinning to regulate the crop in the years when more clusters develop than the vine can bring to perfect maturity may overcome this situation and appreciably increase the average yield over a period of years. If the spurs must be left very long, however, it will be difficult to maintain the form of the vine.

CORDON PRUNING

The characteristic of cordon pruning which distinguishes it from other systems is the much elongated trunk which bears arms over the greater

part of its length. Instead of the usual 1 to 3 feet or at most 4 feet, it is extended 5 to 10 or more feet. In practice three types of this system are used, namely the bilateral and unilateral horizontal cordons and the vertical cordon. The trunk of the bilateral cordon rises to 15 to 30 inches or more where it is divided into two parts each of which continues through a quarter circle to the desired height and then extends horizontally in opposite directions to the next vine (fig. 14). In the unilateral horizontal cordon the shape of the trunk is similar to the bilateral, except that it extends only in one direction and its end overlaps the bend of the next vine (fig. 15). The trunk of the vertical cordon is erect over its entire length (fig. 16).

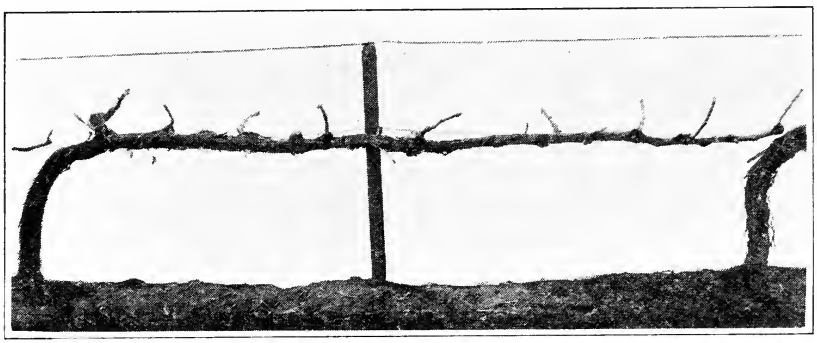


Fig. 15.—A mature, horizontal unilateral cordon-pruned vine.

The vines of the cordon system have no definite head. The arms are distributed over the greater part of the trunk at intervals of 8 to 12 inches. In the horizontal cordons the arms should arise only on the upper side of the horizontal part of the trunk. If this is not the case, the fruit will not be exposed uniformly to light and air. The arms of the vertical cordon are distributed around the trunk from its top to within 12 to 15 inches of the soil. At the end of the arms, at each winter pruning, are left spurs. These spurs produce shoots which bear the next crop of fruit and supply wood for the next year's spurs. This system of pruning thus consists of cordon training and spur pruning.

Cordon vines may be and in some regions are cane pruned. This, however, is inadvisable since there is nothing to be gained over the cane pruning of headed vines. Also it is very difficult to maintain the shape or form of a cordon vine when cane pruning is practiced.

Pruning Mature Cordon-Pruned Vines.—Since the annual pruning of the cordon vine consists in the leaving of spurs, it is similar to head pruning or any other system of spur pruning. In choosing the wood and estimating the number of buds to be left the pruner proceeds in the same

manner as outlined for head pruning (page 39). Several types of cordon pruning are illustrated in figures 14, 15, and 16. To maintain the capacity of the individual arms at the same level great care must be used to regulate the length of the spurs left in accordance with the size of the canes of which they are the basal parts. Since the arms of the horizontal cordon are upright the most vigorous growth is usually at the ends of the spurs, hence the arms may tend to become too long very rapidly unless the wood for the spur is very carefully selected and judicious use is made of replacement spurs.

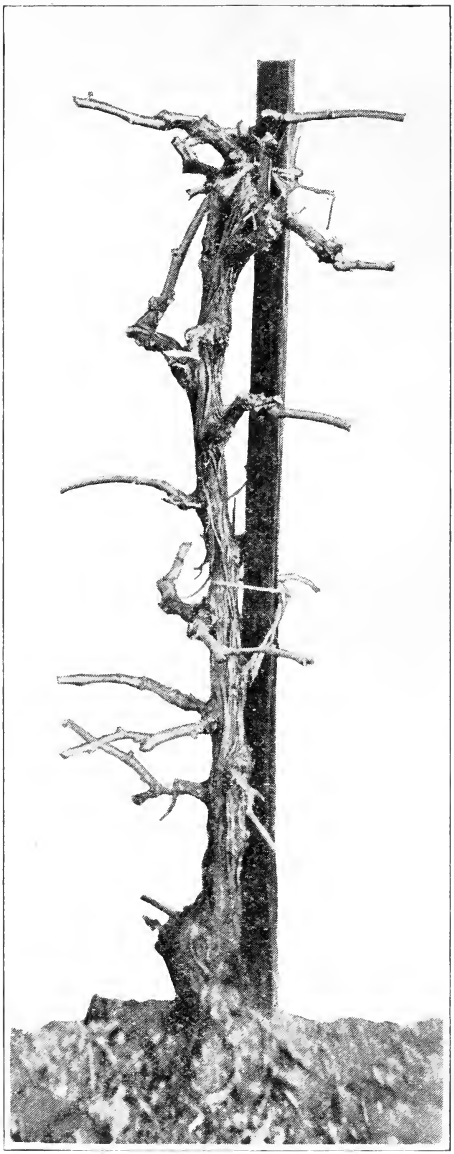


Fig. 16.—A mature, vertical cordon-pruned vine. (From Bul. 241–246.)

Advantages of Cordon Pruning.—The length of the trunk of cordon-pruned vines distributes the crop well; the clusters do not touch each other. In the case of the horizontal cordons the shoots do not come against or grow through the clusters. The clusters are thus more perfect and can be more easily harvested without injury. These cordons place all of the clusters at about the same distance from the ground. This favors uniformity in the development of the factors which constitute quality, such as color, size, and sugar content.

The extension of the trunk in cordon pruning tends to make the buds on the lower part of the canes more fruitful. Some varieties which require very long spurs or fruit canes with head pruning bear fair crops on spurs of normal length when pruned by the cordon system.

Pruning cordon vines to spurs reduces the pruning cost to a minimum. In fact the pruning of a well-trained cordon vine is perhaps the simplest and hence the cheapest of any system.

Disadvantages of Cordon Pruning.—The greater length of the trunk of the vines of the cordon system makes it the most laborious of the three systems to establish. Not only is more work required to establish the vines of these systems, but the labor employed must be much more skilled and must exercise greater care than is necessary with head and

Fig. 17.—A mature Emperor vine, showing the combination of cordon training and semi-cane-pruning of this variety.

cane pruning. This combination of greater skill and more work required for the training of cordon vines makes them the most expensive to establish. Of the three types of cordons the vertical is the least difficult and the unilateral the most difficult to establish.

The vertical cordon, however, has defects which possibly overshadow any and all of its advantages. One of these is that the fruit is subject to various degrees of temperature and shading in different parts of the vine, thus the ripening and coloring are often uneven. A more vital defect is that it cannot be maintained permanently. The arms and shoots at the top of the trunk tend to become more vigorous and the lower arms and shoots, as a result of shading, become weaker each year until finally no growth at all is obtained below. After a time, therefore, most of the vines lose the character of cordons and become simply headed vines with rather long trunks which are weak and short-lived owing to the large wounds where the lower dead arms were removed.

As a result of this tendency of the vertical cordons to lose their form, the present practice in the Emperor region of the San Joaquin Valley, where this system has been widely used, is to develop the Emperor vines to a high short bilateral cordon. A one-wire trellis is employed to support the cordons. The mature vines are then semi-cane-pruned, leaving long spurs on the cordons and one short cane at the end of each cordon (fig. 17). The length of the canes as well as the number and length of the spurs will depend on the capacity of the vine.

Fig. 18.—A mature cane-pruned vine. (From Bul. 519.)

The horizontal cordons in addition to being difficult to establish require trellising which further increases the cost of these types.

Neither of the types of cordon pruning overcomes the tendency of certain varieties to produce straggly clusters or to set shot berries. As stated under the disadvantages of head pruning, these defects are associated with the restricted leaf development early in the season on short spur-pruned vines. Pruning to canes with flower-cluster thinning to regulate crop reduces these defects. However, as indicated on page 43, the cane pruning of cordon vines is impractical under most conditions.

CANE PRUNING

In cane pruning the vine is given a trunk or stem of similar form to that of head pruning. The head of the vine differs in that it is fan shaped in the plane of the trellis and the arms do not extend in all directions as in head pruning (fig. 18). This is necessary for convenience and economy of cultivation which can take place in only one direction. Also, a considerable number of shoots arising from a fruit cane produce more fruit than the few shoots of a spur, hence few canes are needed and therefore few arms are necessary to produce these canes. Two arms on each side of the head are all that are required by a vine in full bearing.

In head and cordon pruning, the spurs have two functions, namely, the production of fruit and the production of canes for the following

year. In cane pruning these functions are separated. The fruit cane bears the fruit while the production of canes for the following year is left largely to the renewal spur. The renewal spur is usually cut to two buds, one of which is expected to produce a cane which can be cut back the next year to 2 to 5 feet for a new fruit cane and the other to two buds for a new renewal spur. Each year the fruit cane which has borne is cut off and replaced by a new fruit cane. Thus, cane pruning consists of head training and the retention of both fruit canes and renewal spurs at each annual pruning.

Pruning Mature Cane-Pruned Vines.—The amount of fruiting wood (canes) to be retained on mature vines depends on the capacity of the individual vine. This can be best determined by observing the number and growth the canes made the previous season together with an estimate of the amount of fruiting wood the vine had. A vine with canes of normal size should have about the same length of fruit wood as was left the previous season. A vine with canes above normal in size should have more fruiting wood than was left the previous year, while one with canes below normal size should be treated so as to bear less crop.

The length of the fruit canes should be from 2 to 5 feet or from ten to fifteen buds. Canes with internodes of short to medium length will have ten buds on the lower 2 feet, while very vigorous canes with relatively long internodes must be left 5 feet long to have fifteen buds. Only well-ripened wood, of good thickness, but not overgrown should be used for fruit canes. In the very hot regions where the growth is usually very vigorous some of the laterals with well-matured buds should be left on the canes and cut back to spurs. The thicker and longer the canes are, the longer should be the fruit cane retained from them.

The maximum length of fruit wood for a single vine is 16 to 25 feet. This is ample for the largest crop for a vine at the usual planting distances. Nothing is to be gained by leaving a greater length of fruiting wood since an excess in this respect is sure to bring on overbearing, which results in poor quality of the fruit and weakens the vine unless much and careful thinning of the fruit is done.

At each winter pruning the fruit canes which produced the previous season's crop are cut off and replaced by new fruit canes. In cases where the renewal spurs fail to give a sufficient number of suitable canes, as often happens in some regions, canes that have arisen from dormant buds on the arms of the vine or canes from near the base of the fruit canes of the previous year may be utilized for fruiting wood. The latter canes should be used as seldom as possible, because this tends to cause the arms to elongate very rapidly. On most varieties including Thompson Seedless (Sultanina) a water-sprout, provided it developed early

in the season so that it is well matured, makes a perfectly satisfactory fruit cane. In order to prevent the arms elongating too rapidly it is necessary, whenever possible, to have the renewal spurs nearer the head of the vine than the fruit cane. Where it is necessary to leave a renewal spur pointing at right angles to the line of the row, it should be shortened to 3 inches or less so that it will not be broken during cultivation. If the vine is vigorous, base buds will grow and such a spur will supply the two canes needed; that is, one which can be used as a fruit cane and another which can be used for a renewal spur. Also replacing spurs, to shorten long arms, must be used occasionally as in the other systems of pruning.

Advantages of Cane Pruning.—The most generally recognized advantage of cane pruning is the possibility of obtaining full crops of fruit on varieties of which the buds near the base of the canes are sterile. The pruning of Thompson Seedless is an example of the utilization of cane pruning for this purpose. Likewise, the long pruning of the Riesling varieties is an example of the use of this type of pruning to insure full crops on varieties of which the clusters are very small. In fact these are the only merits of this system of pruning that had been widely recognized until a very few years ago.

With the use of thinning to regulate the crop, cane pruning offers two other advantages. First, it makes the spreading of the fruit over a larger area possible. In cordon pruning the fruit is spread from vine to vine, while in cane pruning the fruit can be spread not only from vine to vine but also laterally as well. The wide-top trellis greatly enhances the possibilities in this latter direction. Second, cane pruning accompanied by flower-cluster thinning several weeks before blooming reduces the tendency of certain varieties, such as Muscat of Alexandria, to produce shot berries or straggly clusters. Cane pruning allows the vine to make a greater development early in the season than any other pruning system. At the time of blooming, other conditions being equal, cane-pruned vines will have produced one-half to several times more leaves than spur-pruned vines. With the same number of clusters to a vine, the clusters on the cane-pruned vines are better nourished.

Cane pruning is the least severe of the systems of pruning in general use. Thus, it allows for the greatest development of the vine. Cane-pruned vines will produce considerably more fruit than spur-pruned vines and still make an equal amount of growth.

Disadvantages of Cane Pruning.—Cane pruning of any variety that has been producing full crops with spur pruning will result in overbearing and in the production of fruit of poor quality unless it is severely thinned. This is due to the fact that more buds are retained with this

system of pruning and that the buds on the canes of practically all varieties become more fruitful from the base upward over the length usually retained in cane pruning.

To obtain the benefits of spreading the fruit with its favorable influence on quality it is necessary that cane-pruned vines be trellised. This need for a trellis adds to the cost. Supporting the canes without a trellis is unsatisfactory since it tends to mass the clusters close together.

Cane pruning is the most difficult system. Since the units retained are relatively few in number each must be more nearly perfect if regular full crops are to be produced. The selection of one poor cane may mean the loss of one-fourth of the crop of the vine. Thus, great care must be exercised in the selection of the wood to be retained. More care is also required with this system of pruning to maintain the form of the vine. In spur pruning the units are relatively very short, hence the vine cannot get out of shape very fast. This is not true of cane-pruned vines. Here the units may be very long and if the pruner is careless in the selection of wood the vine will be out of shape in a few years. It may then be impossible to find suitable fruit wood close to the head of the vine.

DEVELOPING YOUNG VINES

In developing young vines the form required in the mature vine must be known. Otherwise mistakes will be made and the mature vine will be defective. Defectively formed vines can, in some instances be corrected, but to do so is costly and always requires the making of large wounds. Figures 13, 14, 15, and 18 show well-formed mature vines of the types generally used in California.

FORMING HEAD (SPUR) PRUNED VINES

Pruning at Planting.—When a rooted or grafted vine is planted the roots should be shortened to from 3 to 6 inches for economy in planting, and all the new growth of the top removed except one cane which should be shortened to two buds (fig. 19).

Planting and Care the First Summer.—When vines on their own roots are planted, only the two buds should show above the surface of the ground, while with grafted vines the graft union should be just above the surface of the ground. As a rule no summer pruning should be done and staking is unnecessary. The only exceptions to this are in some regions where the heat, soil, and water conditions are so favorable to quick development, that the work of two seasons can be done in one. The treatment in these cases during the first year is identical with the treatment for the second year described here for more usual conditions.

First Winter Pruning.—At the end of the first growing season, the young vine should have made a growth aboveground of one or more canes from 1 to 3 feet long and a strong, widely spreading and penetrating root system.

The tops are pruned in winter after the leaves have fallen. Only one cane is reserved and this usually cut back to two buds. (See fig. 20*A*.)

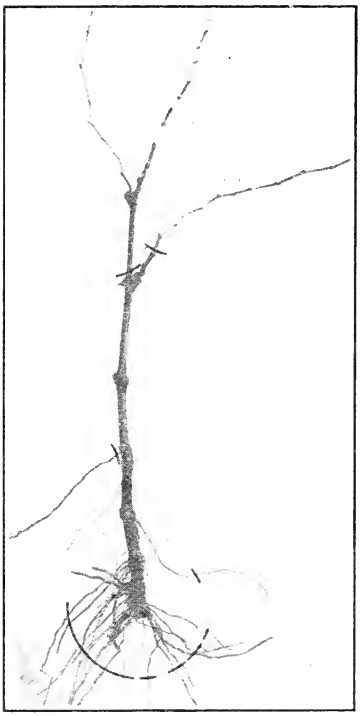


Fig. 19. — One-year-old rooted vine. The marks indicate the pruning at planting. (From Bul. 241–246.)

The vine after pruning, therefore, looks, above the ground, almost as it did when planted the previous spring. Its condition, however, is very different. It is now supplied with a complete root system and is prepared to make a very much larger growth during the coming season.

Its work during the second season is to produce a single strong cane from which a trunk can be developed. To do this, it requires not only favorable conditions for growth, but support and training during the spring and summer.

As soon as possible after pruning, the vineyard should be staked with 3, 4, or 6-foot stakes according to the height desired to raise the head.

Well before the vines start to bud in the spring, a single furrow should be thrown away from each side of each row of vines and the ridge hoed away for 6 inches on both sides of the vine. This will expose suckers and surface roots and allow them to be removed completely with a sharp pair of pruning shears without leaving stubs to produce more suckers and surface roots the following years (fig. 20*B*). If this is neglected or improperly done it may be the cause of much trouble and expense later. Vines properly suckered and surface-rooted during the first two years give no trouble in this respect later.

Second Summer Treatment.—In the spring, as soon as a large portion of the vines have each produced a shoot 2 to 4 inches long, they should receive the first disbudding. This consists of rubbing off every shoot or swollen bud but the one which is well placed to be tied to the support (fig. 21).

The reserved shoots will then grow rapidly and as soon as they are 6 to 12 inches long the vines should be disbudded the second time. This consists in rubbing off any new buds or shoots that have developed since the first disbudding (fig. 22*A*). At this time, any vines which had not started before are disbudded for the first time. Also any shoots which

A *B*

Fig. 20.—First winter pruning: *A*, pruning the top; *B*, removal of suckers and surface roots. (From Cir. 277.)

A *B*

Fig. 21.—First disbudding during second summer: *A*, before disbudding; *B*, after disbudding.

have grown over 8 inches are tied loosely to the stake with a piece of jute twine or other soft string (fig. 22*B*). In windy locations earlier tying may be advisable.

Later, as soon as the shoots have grown 12 to 15 inches more they are tied again nearer the top of the stake. With vines trained to high stakes three or more tyings are usually necessary (fig. 22*C* and *D*).

Only buds and shoots on the old part of the vine should be removed. Nothing should be taken from the reserved shoot which is growing.

Side shoots (laterals) will start on vigorous reserved shoots in the angles (axils) where the leaves are attached to the shoot (fig. 22*D*). These should not be removed. If any of these laterals below the middle of the main shoot show signs of developing as rapidly as the main shoot they should be pinched, that is, an inch of the growing tip should be pinched off when they are 12 to 15 inches long (fig. 22*D*).

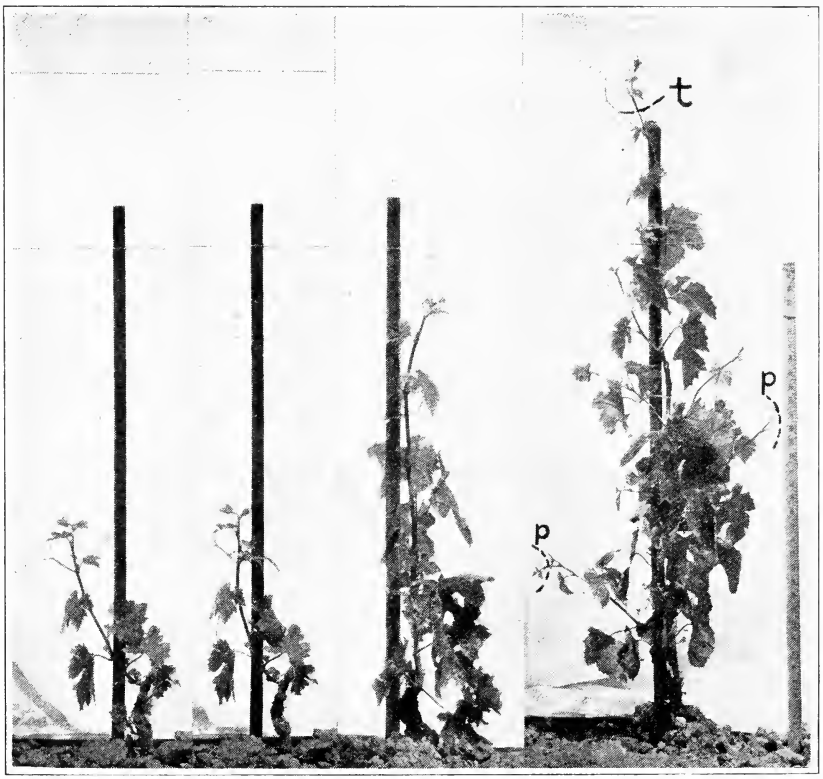
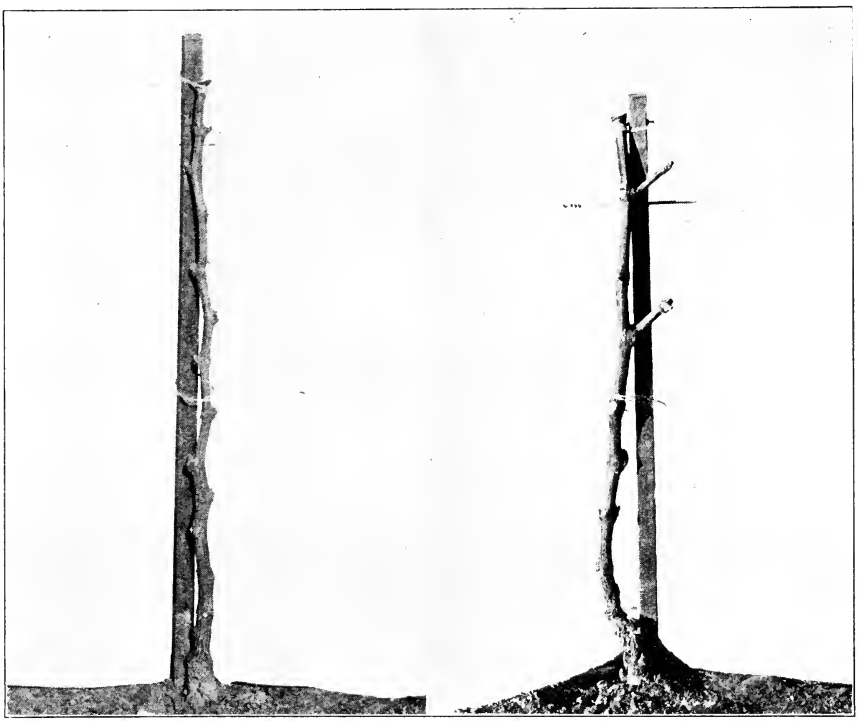


Fig. 22.—*A*, Before the second disbudding; *B*, after disbudding; and *B*, *C*, and *D*, tying the reserved shoot to the support during the second summer. Strong growing low laterals are pinched at *p* to check their growth. When the main shoot has grown 8 to 12 inches above the height at which the head is to be formed it is topped, as indicated at *t*.

When the main shoot has grown 8 to 12 inches above the point where the head is desired it should be topped (fig. 22*D*). This will tend to encourage the growth of laterals. All laterals on the upper half of the shoot should be allowed to grow without pinching unless they seem in danger of being broken by the wind, in which case they are pinched like the lower laterals.

Second Winter Pruning.—After the leaves have fallen, at the end of the second growing season, the vines should receive their second winter pruning. In frosty locations it is better to defer the pruning until a few days before the buds start in the spring.

Each vine will consist of a single straight cane tied vertically to the stake together with its laterals. If well grown, this cane should be cut off at the node (joint) above the level at which the head is desired. This



A *B*

Fig. 23.—The second winter pruning: *A*, an average vine; *B*, a vigorous vine. (From Cir. 277.)

cut is made in such a way as to destroy the bud but to leave the enlargement of the node. This is to facilitate secure tying (fig. 23).

All small laterals and all laterals below the middle should be removed. On exceptionally large vines, laterals over $\frac{3}{10}$ inch thick on the upper half of the cane should be cut back to one or two buds, according to their strength. These will act as fruiting spurs and help to develop the head rapidly (fig. 23).

Vines on which the cane is less than $\frac{3}{10}$ inch thick at the desired height of the head should usually be cut back to two buds as at the first winter pruning (fig. 20).

To permit close plowing and cultivation as well as other vineyard operations the trunk of the vine should be as nearly straight and vertical as possible, hence before the buds swell in the spring, the pruned cane which will be the trunk of the vine should be tied securely to the stake. A single hitch, double half hitch, or clove hitch is made around the cane just below the enlargement of the node that was cut through and the string tied around the stake as tight as possible with a firm square knot (fig. 23). A loose tie is then placed around the stake and cane about the middle. This tie should not pass around the cane between the cane and the stake, or the vine will be girdled. If two fingers can be inserted between the cane and the string the danger is avoided.

When they develop again during the second summer, the suckers and surface roots should be removed thoroughly and carefully as was done the previous year.

Third Summer Treatment.—During the second summer, a cane was produced which will develop into the permanent trunk. During the third summer a small or medium crop will be produced and the development of the head begun.

The complete formation of the head will require at least three seasons except under the unusually intense growing conditions already referred to. An attempt to form the head too rapidly will result in loss of crop and the production of ill-shaped vines.

During the summer, all the shoots which start on the lower half of the trunk cane are removed as soon as possible after they start (fig. 24). To allow them to grow 6 or more inches and then remove them stunts the vine and delays its development. Usually a second disbudding is necessary (fig. 25*d*). All shoots which start on the upper half should be allowed to grow without interference. Only in cases where the shoots grow so large and with such rapidity that they are in danger of being broken by the wind should they be given any attention. In this case it is usually sufficient to pinch the tips when the shoots are about 18 inches long (fig. 25*p*). It may be necessary to repeat the pinching in very windy locations.

Completing the Head.—At the end of the third growing season, after the leaves have fallen, an average good vine will consist of a well-developed trunk from 1 to 2 inches thick, bearing on its upper half from four to eight strong, well-matured, healthy canes.

Enough of these canes should be reserved and cut back to spurs to bear the crop that the vine is judged capable of bearing without injury to its vigor and the proper maturing of the grapes. This will usually be from three to six according to the vigor of the vine. Each spur should be cut back to two, three or four buds according to the size of the cane

from which it is retained. These spurs should be as near the top of the vine as is possible (fig. 26).

During the summer no pruning will be needed except the removal, as soon after they start as is practicable, of all shoots that start below the

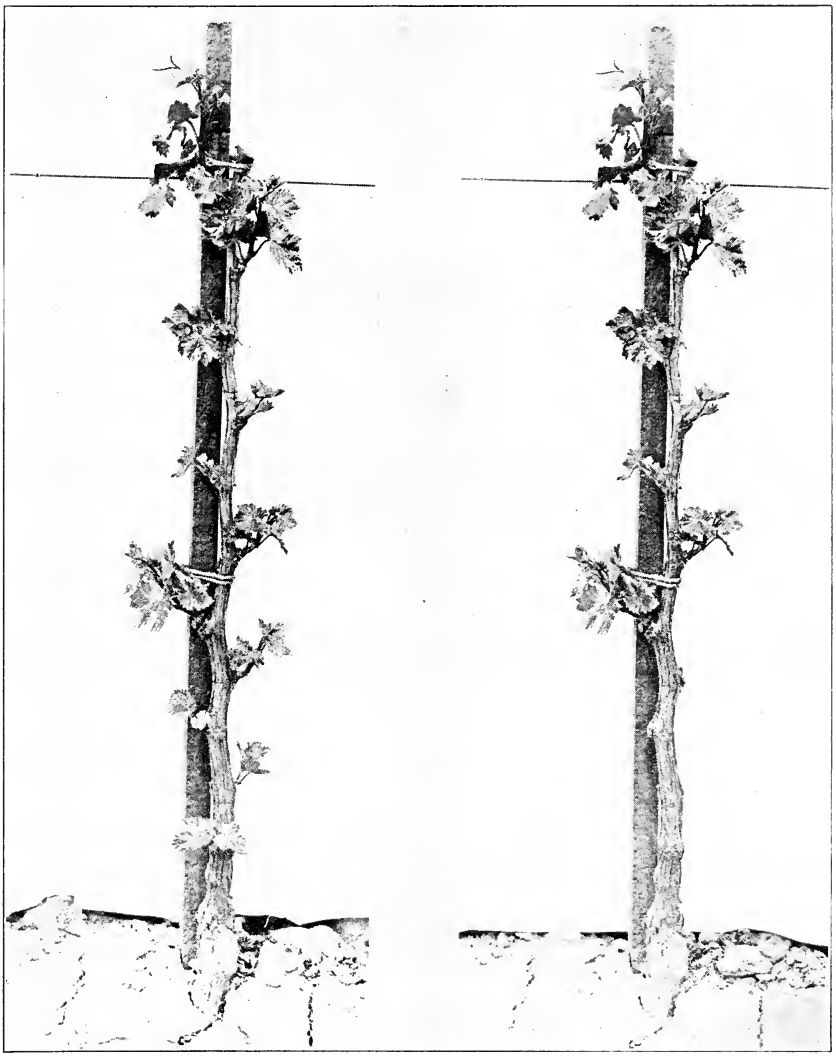


Fig. 24.—The first disbudding during the third summer. (From Cir. 277.)

bottom spur and of all suckers that come from below ground. Pinching of the vigorous shoots when they are 18 to 20 inches long may be necessary in windy situations.

At the end of the fourth growing season each of the spurs of the last

winter pruning should have produced one, two, or more canes sufficiently vigorous to use for spurs. Beginning as near the top of the vine as possible, the spurs should be spaced evenly around the trunk and as

Fig. 25.—The second disbudding and pinching during the third summer. All shoots starting on the lower half of the trunk cane are removed as indicated at *d*. Strong growing shoots may be pinched at *p* to avoid breakage by wind.

nearly as possible in a horizontal plane, that is, the same distance from the ground. A sufficient number of buds should be retained to give the crop that the vine is capable of bearing. On vigorous vines the spurs

may be left long and the crop controlled by thinning, which spreads the head rapidly and obtains a large framework on which to produce the fruit early in the life of the vine. All growth below should be removed. This will usually leave all the spurs on the upper third of the vine (fig. 26).

The summer treatment during the fifth growing season is identical with that of the fourth. No topping should be done, nor even any pinching, unless it is absolutely necessary to prevent serious wind damage.

Fig. 26.—The formation of the head: *A*, the third winter pruning; *B*, the fourth winter pruning; *C*, the fifth winter pruning.

The fifth winter pruning is a continuation of the method of the fourth. Spurs should be chosen at the top of the vine in such a way as to give the head and arms as nearly as possible the desired form and in sufficient number to give the amount of crop suited to the size and vigor of the vine (fig. 26*C*).

For the pruning of mature head-pruned vines see page 40.

FORMING CANE-PRUNED VINES

Wherever cane pruning is used in California it is on vines that have been developed to a head. Thus, the treatment of vines to be cane pruned is, during their early development, the same as that for head-pruned vines. This is true up to the end of the third growing season; hence for directions during the first three seasons see the section "Forming Head (Spur) Pruned Vines," page 49.

The head of the cane-pruned vines is fan-shaped. The arms extend in the plane of the trellis and not in all directions as in head pruning. The number of fruit canes to leave at the third winter pruning will depend on the size of the vine. An average vine will need only one, with two or three renewal spurs (fig. 27). Care must be exercised in the selection of renewal spurs at this time, since they will form the permanent arms of the vine. The fruit cane or canes should be tied in such a way that most of the weight will fall on the wire of the trellis and not on the string by

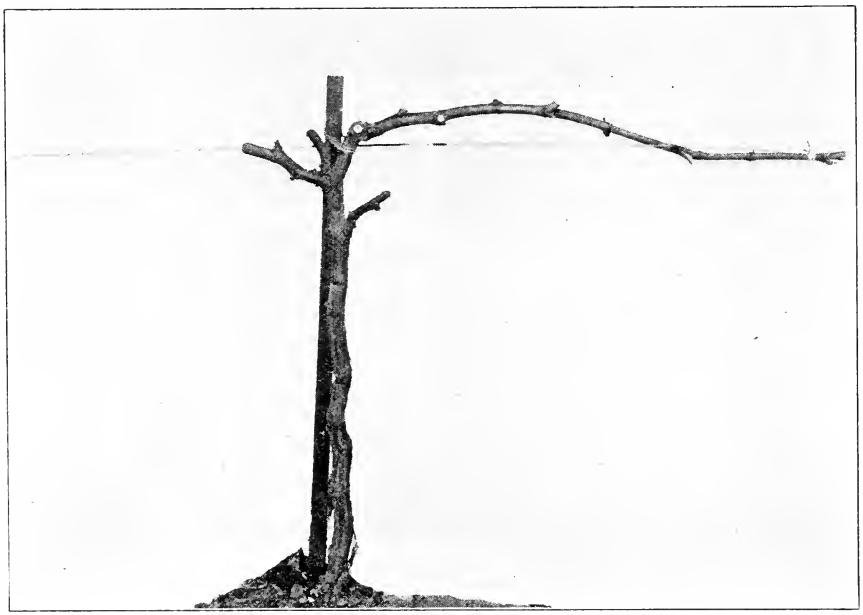


Fig. 27.—The third winter pruning of a cane-pruned vine. (From Cir. 277.)

which they are tied. This is accomplished by giving the cane about one turn around the wire and tying firmly at the end. No other tie is needed in most cases, except that supporting the head. The canes, when tied, should not be twisted several times around the wire, because this makes it difficult to remove them at the following winter pruning.

The summer treatment for cane-pruned vines at this stage of development is the same as that indicated for the four and five-year-old head-pruned vines. The next year the vines will be capable of supporting two or three canes, with four or five renewal spurs. Great care should be taken to have the renewal spurs so placed that the arms which will be gradually formed from them will be in the line of the trellis (fig. 28). If the arms jut out into the space between the rows, they interfere with cultivation and are in danger of damage from implements.

Directions for the pruning of mature cane-pruned vines are given on page 47.

The Trellis.—For the support of the fruit canes and their crop, a trellis is needed. The most generally used trellis consists of two wires stretched along each row from posts at the ends of the row. Permanent stakes are placed at each vine or at each second vine and pickets at the intervening vines.

The lower wire is at the height of the head of the vine (24 inches to 36 inches high) and the upper wire 12 to 15 inches higher. The fruit

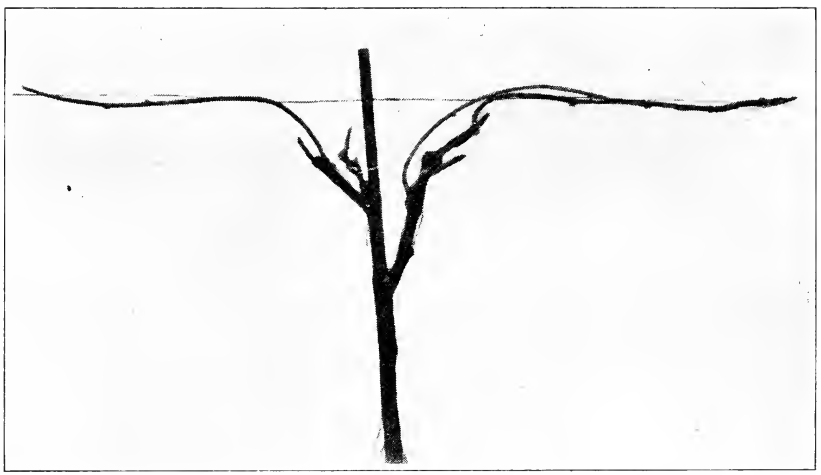


Fig. 28.—The fourth winter pruning of a cane-pruned vine.

canes are tied to the lower wire. The upper wire is simply to support the shoots from the fruit canes and the renewal spurs to protect them from wind damage; also to keep the fruit off the ground and to protect it from exposure to the direct rays of the sun. The trellis should be put up at the end of the first growing season.

Recently, wide-top trellises have begun to find favor with table-grape growers. Through the use of these trellises it is possible to obtain a greater spread as well as a more uniform exposure of the clusters. The wide-top trellises are usually additions to the standard two-wire trellis and are made by stringing additional wires on cross arms at the top of the stakes.

FORMING CORDON-PRUNED VINES

The treatment during the first year is exactly the same as for head-pruned vines. Since all cordon-pruned vines have long trunks it is necessary that the canes from which they are formed be vigorous. Hence, it is often advisable to cut the vine back to the ground after the second as

well as after the first growing season and to take three years to form the trunk.

The proper training of cordon vines requires more careful and skilled hand work during the second, third, and fourth years than the development of the headed vines. If the system is not carried out skillfully and carefully with a full knowledge of the proper methods, the vines will get into a condition which is worse than is likely with other systems. However, there is nothing very difficult to understand or to do in properly

A B

Fig. 29.—Placing the growing shoots of a horizontal bilateral cordon on the wire.

establishing a cordon, but the grower must be sure he understands the method and be prepared to do all that it requires if he is to make it a success.

Forming the Trunk of Bilateral Horizontal Cordons.—At the end of the first, and if necessary the second, season the vine is reduced to a single cane and this cane cut back to two buds (fig. 20).

A trellis with two wires similar to that recommended for cane pruning is then put up. During the following summer, the treatment is the same as that described for headed vines up to the time the vine reaches almost the stage of development shown in figure 22*D;* that is, when the vine has grown about 8 inches beyond the point at which the trunk is to be divided to form the two branches which should be 6 to 10 inches below the bottom wire of the trellis. At this stage the tip of the main shoot is pinched to cause the formation of strong laterals. After the laterals have made 12 to 18 inches of growth, two of the best placed are selected and tied up to the stake or picket. These two laterals should arise on opposite

sides of the main shoots and in the plane of the trellis. The other laterals are pinched back, or in the case of a very vigorously growing vine, removed entirely. When the selected laterals have grown about a foot above the top of the support (fig. 29*A*) all ties are removed except those on the main shoot. A lateral is then bent over in each direction along the trellis and tied loosely to the bottom wire (fig. 29*B*).

A *B*

Fig. 30.—Developing a horizontal unilateral cordon vine. *A*, The reserved shoot tied to the stake; and *B*, placing the shoot on the wire. (From Cir. 277.)

Each lateral shoot is then tied again once or twice as they lengthen. No tie should be placed nearer than about 15 inches from the growing tip or the elongation may be checked by bringing the tip down in a horizontal position. If the shoots grow long enough, they are pinched after they have grown about 2 feet beyond the half-way point to the next vine.

The trunk of the bilateral cordon may also be formed by allowing the main shoot (fig. 30*A*) to develop until it is 2 or 3 feet higher than the bottom wire. It is then untied and bent over on a radius of 6 to 10 inches, a shorter radius than that shown in figure 30*B*, and tied to the bottom wire of the trellis to one side of the vine to form one branch of the trunk. The relatively short bend in the main shoot causes the lateral at or near the lower part of the bend to develop vigorously. This lateral is then tied to the bottom wire in the other direction to form the second branch of the trunk. If the main shoot tends to grow too vigorously, it may be pinched which will check its growth and give the lateral a chance to catch up. Additional ties will be required as the shoot and lateral grow. Pinching as indicated for the method using the two laterals will be necessary.

Pruning the Trunk Canes of Bilateral Horizontal Cordons.—At the end of the season, after the leaves have fallen, the trunk canes should be cut back to a place where they are at least ½ inch thick. If they have grown sufficiently, they may be allowed to extend to the point of junction with the adjoining vines. If the canes are not sufficiently large to reach at least 12 inches along the wire beyond the bend, they must be cut back to the point at which the trunk was divided and more vigorous canes grown the next year. It is a mistake to retain canes that are too small.

Forming the Trunk of Unilateral Horizontal Cordons.—The difficulties of establishing this type of cordon are somewhat greater than those of establishing the bilateral type owing primarily to the greater vigor necessary to form the longer trunk cane. During the second summer, the treatment is the same as that described for head pruning up to the time the vine reaches the stage shown in figure 22*D*. After this stage the strong laterals are pinched as shown in figure 22*D*, but the end of the shoot is allowed to grow until it is about 2 feet above the top wire (fig. 30*A*).

At this stage all the ties are removed except the lowest one at 8 to 10 inches from the ground. The shoot is then bent over on a 12 to 15-inch radius and tied loosely to the lower wire of the trellis (fig. 30*B*).

This shoot is then allowed to grow and is tied again once or twice to the wire as it lengthens. No tie should be placed nearer than about 15 inches from the growing tip or the shoot may be stunted. If the shoot grows long enough, it is pinched after it has passed the bend of the adjoining vine 1 to 1½ feet.

Pruning the Trunk Cane of Unilateral Cordons.—At the end of the second season, after the leaves have fallen, the trunk cane should be cut back to a place where it is at least ½ inch thick. If it has grown sufficiently, it may be allowed to extend to the top of the bend of the adjoining vine. If it has not made a cane sufficiently large to reach at least 12

inches along the wire beyond the bend, it must be cut back to within 6 to 8 inches of the ground and a more vigorous cane grown the next year from which to form the trunk. Many failures are due to the use of small canes for forming the trunk.

Tying the Trunk Canes of Horizontal Cordons.—In both bilateral and unilateral systems the canes are straightened by turning them around the wire once or twice according to their strength. They should not be turned around the wire more than is necessary to make them straight, and in any case, not more than twice, and this only with unilateral

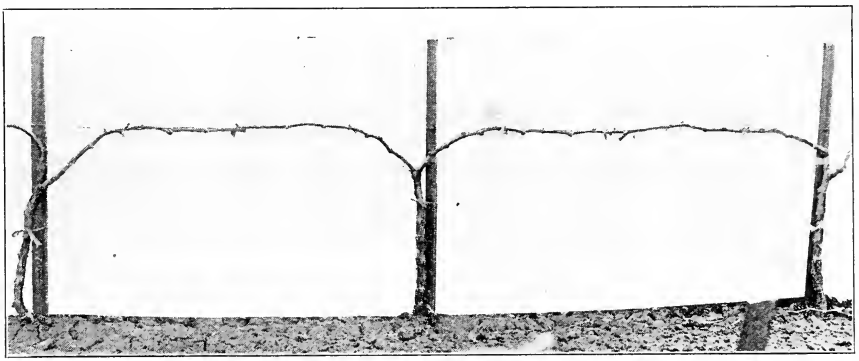


Fig. 31.—The completed trunk of a horizontal bilateral cordon vine tied to the wire—third winter. (From Cir. 277.)

cordon canes of full length. If twisted too many times, they will be cut by the wire as they grow and will be injured or broken the next year when it becomes necessary to untwist them (fig. 31).

The end of the canes should be tied firmly to the wire around the stub projecting beyond the end bud. If there then remain any parts of the canes which are not close to the wire, these should be straightened by other ties. It is very essential that the horizontal portion of the trunk canes be straight. The ties, except the one at the end of the trunk cane, should be loose enough to allow for the growth of the cane, which may reach 1 to 2 inches in diameter during the summer.

Establishing the Arms.—During the first season the cordons are on the wires the first crop will be borne, and the vine will produce canes from which to start its arms.

Two serious dangers are to be avoided. One is the production of too much crop. This will result in grapes of poor quality and weakening of the vine which will prevent it from producing the good canes necessary for spurs the next year. The other is the development of shoots on the lower side of the trunk cane instead of on the upper side.

While the buds are starting in the spring, the vineyard should be gone

over several times and the shoots starting on the underside of the cane rubbed off. This will remove half the shoots and leave the other half, spaced 6 to 10 inches apart on the upper side. This disbudding should be done as soon as possible, and no shoot which is to be removed should be allowed to grow more than a few inches. At the same time all shoots starting on or below the bend should be removed, except one or two on the upper part of the bend which are pinched back, leaving three or four leaves on each to shade the trunk (fig. 32).

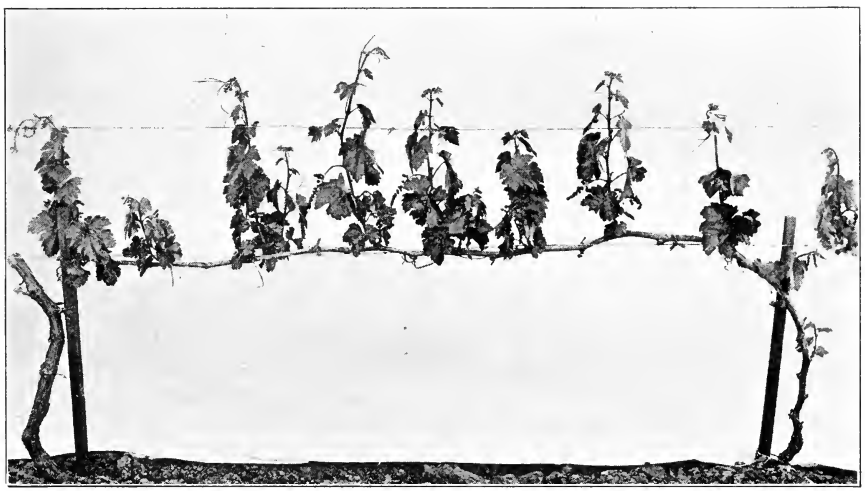


Fig. 32.—A horizontal unilateral cordon, first year on the wire. Shoots ready for tying to the upper wire. (From Cir. 277.)

As the shoots on the upper side grow at uneven rates, some of them will soon be much longer than the others. These long shoots are usually near either the bend or at the end. They should be pinched as soon as this can be done without injuring the blossom clusters, which are usually at the third and fourth nodes. This pinching will check the growth and allow the weaker shoots to catch up with the others (fig. 32).

On vines which do not extend the full length, a shoot should be allowed to grow from near the end to complete the trunk. This shoot should be tied to the wire so as to make the extension of the trunk as straight as possible. A shoot from the underside of the cane is best for this purpose.

As soon as the shoots are sufficiently long (fig. 32), one, two, or three of them should be tied to the upper wire. If this is not done, the weight of all the shoots which start on the upper side of the trunk cane, together with that of the fruit they bear, will be so great as to turn the trunk cane completely over and leave the upper side bare and the canes all pointing

towards the ground. If this happens the vine can never be made into a successful cordon.

The tying of supporting shoots is necessary only the first year because the second year the trunk is sufficiently thick and rigid to prevent turning. In very windy locations, however, it is useful to tie the first strong shoots, even of older vines, to prevent breakage by the wind.

Pruning the Completed Cordons.—The first winter pruning after the trunk cane has been completed on the wire consists in leaving spurs along the upper side of the horizontal part of the trunk. These spurs should be spaced as evenly as possible, 8 to 14 inches apart. The length of the spurs will be from one to four buds according to the vigor of the vine and the individual canes. In case there is no cane on the upper side where a spur is needed a cane from the lower side must be taken. By cutting this back to one bud a strong shoot will be obtained which, when it has grown long enough, can be tied to the upper wire so that it will provide a vertical cane for the next year.

CHOICE OF A PRUNING SYSTEM

Whatever the system of pruning adopted, the choice must be made before the vineyard is planted if all of its benefits are to be obtained. In deciding upon a system, its advantages, disadvantages, probable cost, returns, and practicability should be considered, as well as its suitability to the variety of the vines, the soil, and climate, and the use to be made of the fruit.

Head Pruning.—For the most economical production of all varieties of grapes that bear well with spur pruning, and where appearance of the fruit is not of foremost importance, head pruning should be used. With most varieties of wine grapes, such as Zinfandel, Carignane, Burger, Mataro, and Mission, and with Muscat of Alexandria for raisin production this system is satisfactory. By leaving longer spurs and employing the requisite method of thinning for the variety, head pruning has given very good results with such table grapes as the Tokay, Molinera, and Malaga. It requires the least outlay of capital for stakes or other supports and is the most economical in the cost of pruning.

Cane Pruning.—With varieties of which the lower buds on the canes are usually only wood buds, such as Thompson Seedless (Sultanina), Sultana, Black Corinth, Cabernet Sauvignon, and Semillon, cane pruning must be used. These varieties bear very little with head or cordon pruning.

The crop of other varieties, such as Muscat of Alexandria and Dattier which are subject to coulure and Emperor and Ohanez which are shy

bearers with spur pruning, can be improved by cane pruning accompanied by some form of thinning. With varieties subject to coulure, such as the Muscat of Alexandria, this type of pruning, which results in a greater development of leaves before blooming, causes the flower clusters which are left after flower-cluster thinning to set more perfectly. While with varieties such as Emperor, it insures the development of sufficient flower clusters for a full crop each season and overbearing is prevented by cluster thinning.

Cordon Pruning.—Certain varieties of table grapes, such as Malaga and Cornichon are usually pruned to a high head. This is generally satisfactory, except where they are grown in rich soil with abundant water and heat when the fruit fails to color uniformly or satisfactorily owing to the density of the foliage and crowding of the cluster. Under such conditions cordon pruning should give better-quality fruit since the clusters are spread along the entire trunk and are separated one from another. In fact, cordon pruning may give good results with most of the varieties of very large-clustered table grapes which set fairly perfect clusters with spur pruning, such as Monukka, Danugue (Gros Guillaume), Ribier (Alphonse Lavallée), Gros Colman, Malaga, Tokay, and under some conditions Emperor.

Practicability.—Head pruning is the most generally understood, and if improperly or unskillfully applied, the results are less disastrous than with the other systems. However, no system is profitable unless carried out properly and if the owner of a vineyard will take pains to understand any system and follow it carefully, there is very little more difficulty with one system than with another.

Cane pruning perhaps requires the most experience. The bilateral horizontal cordon system, notwithstanding the greater care and knowledge needed during the first three or four years, can be reduced to a set of practical rules to be followed by any intelligent man more easily than any of the others. But these rules must be known and adhered to.

PRUNING GRAPEVINES FOR ARBORS

Arbors are used commercially only to a limited extent in California. They are used extensively, however, to shade the entrance to houses or to cover porches and garden walks. To meet these needs, they vary greatly in design and size.

Since vines can be trained to almost any form, it is possible, by proper training and pruning, to fit them onto any arbor. Because of their vigor certain varieties cover an arbor more rapidly than others; hence, they are considered good arbor varieties. However, it is possible to grow me-

dium or weak-growing varieties on arbors when they are properly trained and not forced to compete with vigorous growers.

In the training of arbor vines it must be remembered that a strong root system must be developed before attempting to form a long trunk. Without such a root system it will be impossible to obtain a shoot that will be sufficiently large to be retained for a trunk cane.

Overhead Arbors.—The procedure in training vines on an overhead arbor will be the same as that indicated for forming head-pruned vines (page 49 and figures 19 to 23) except that the trunks are longer. In order to favor the growth of the trunk shoot, care should be exercised in pinching the laterals on the lower part of the main shoot. During the third summer all shoots which start on the lower three-fourths of the trunk cane should be removed.

The pruning of vines on overhead arbors is either to spurs or canes, according to the fruiting habit of the variety. That is, such varieties as Tokay, Muscat, Malaga, and Ribier would be spur pruned and varieties such as Thompson Seedless and Sultana would be cane pruned. On an arbor, the head of the vine is too high to interfere with cultivation; hence, the arms of the spur-pruned varieties should be developed into cordons which extend over the top of the arbor. With varieties requiring cane pruning, a definite head is maintained and the fruit canes are spread over the top of the arbor. This disposition of the arms and bearing wood permits the clusters to hang free from one another. Care must be exercised, however, to have the spurs spaced regularly so that no part of the head is altogether devoid of spurs. In the hot regions, unshaded sections of the cordons will sunburn.

Arbors Over Walks.—An arbor over a walk may have horizontal laths or wires spaced at 18 to 24 inches on the supports on one or both sides of the walk. If so, it may be desirable to cover the side or sides as well as the top of the arbor with leaves and fruit. To accomplish this it is necessary to use different vines, trained to different heights; that is, some vines would be trained to the top and others to the different levels at which it is desired to have growth on the sides of the arbor. To attempt to develop side arms at different levels on the trunks of the vines that are also taken to the top of the arbor will result in failure, for the reasons indicated in the discussion of the vertical cordon.

The training of vines for this type of arbor is the same as that for the overhead arbor. Some vines will be headed at the desired levels on the side of the arbor while others will be taken to the top. If the variety fruits well on spurs, the vines for the sides of the arbor are divided into bilateral horizontal cordons at the desired height or heights, while those for the top of the arbor are trained to cordons at that level. The vines

requiring cane pruning are trained into heads with arms at the side levels or on the top of the arbor, according to which part of the arbor they are intended to cover.

Garden Walls.—Vines on walls should be trained to bilateral horizontal cordons. The procedure in training would be the same as that indicated for forming cordon-pruned vines (see pages 59 to 65). When growth and fruit at several levels is desired, different vines should be used for each level. It is impossible to maintain two or three-story vines.

Varieties that fruit on spurs, that is, that can be pruned to short spurs, are best adapted to being grown on walls. With varieties that require cane pruning, the fruit canes should be tied downward. This is to force the development of vigorous shoots near the base of the fruit canes so that they may serve for the fruit canes of the following year.

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